MARINE AND COASTAL ECOSYSTEMS AND HUMAN WELL-BEING

Synthesis

A synthesis report based on the findings of the Millennium Ecosystem Assessment

UNEP

The production of this report has been made possible by the support of the Netherlands Ministry of Foreign Affairs-Development Cooperation

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FOREWORD

Humankind depends on the oceans and coasts for its survival, with one third of the world's population living in coastal areas, approximately 4 percent of Earth's total land area. Global changes and a range of other drivers are causing degradation or loss of ecosystem services. Changes to ecosystem services such as food security and employment of nearly 38 million people in the fisheries industry will cause impacts that will reach far beyond the coastal zone.

The Millennium Ecosystem Assessment (MA) is an international initiative that began in 2001 under the auspices of the United Nations. The MA establishes a collaborative and scientific approach to assess ecosystems, the services they provide, and how changes in these services will impact upon human well-being. More than 1,360 leading scientists from 95 countries carried out the Assessment under the direction of a Board that included representatives of four international conventions—the Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), the Ramsar Convention on Wetlands of International Importance, and the Convention on Migratory Species (CMS)—five United Nations agencies, and international scientific organizations, as well as leaders from the private sector, nongovernmental organizations, and indigenous groups.

This report is a synthesis of the findings from the reports of the MA working groups (conditions and trends, scenarios, response and sub-global assessments) concerning marine and coastal ecosystems. UNEP-WCMC and UNEP's Division of Early Warning and Assessment (DEWA) have coordinated the production of this synthesis report in recognition that the loss of marine and coastal services has impacts on human well-being.

The aim of this synthesis report is to contribute to the dissemination of the information contained within the MA to decision-makers and a wide range of stakeholders of marine and coastal ecosystems through seven key messages. In addition it is envisaged the information contained within this synthesis report will contribute to larger international processes such as the Global International Waters Assessment (GIWA), Global Biodiversity Outlook (GBO), the Global Marine Assessment (GMA), Global Environmental Outlook (GEO), the Regional Seas, the CBD and the Ramsar Convention.

The Netherlands Ministry of Foreign Affairs, Development Cooperation, kindly funded the preparation and publication of this report. This synthesis report has only been possible due to the efforts and commitment of the authors and reviewers, of the MA working groups who contributed their time and knowledge to the development of the assessment. I would like to express my gratitude to the team that prepared this synthesis report.

I hope that this synthesis report will provide a tool that will help those who hold the responsibility for the conservation and sustainable use of our marine and coastal ecosystems through the employment of effective policy, legislative and response options.

Klaus Toepfer
Executive Director,
United Nations Environment Programme

PREFACE

The Millennium Ecosystem Assessment (MA) was carried out between 2002 and 2005 to assess the consequence of ecosystem change for human well-being and to analyse the options available to enhance the conservation and sustainable use of ecosystems. The main findings of the MA were released on March 30, 2005.

The human species, while buffered against environmental changes by culture and technology, is ultimately fully dependent on the flow of ecosystem services. The MA analyses ecosystem services at global and sub-global (local or regional) scales in terms of current conditions and trends, plausible future scenarios, and possible responses for sustainable resource use.

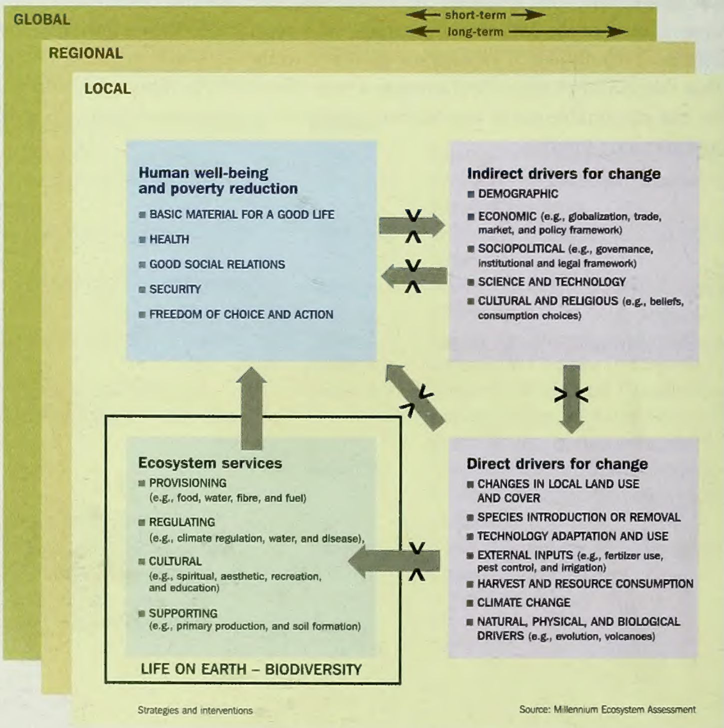
What are ecosystems and ecosystem services?

An *ecosystem* is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. The conceptual framework for the MA assumes that people are integral parts of ecosystems and the Report focuses on examining the linkages between ecosystems and human well-being and in particular on 'ecosystem services', which are the benefits that people obtain from ecosystems. (See Figure A.) Ecosystem services include:

provisioning services such as food, water, timber, and fibre;
regulating services such as the regulation of climate, floods, disease, wastes and water quality;
cultural services such as recreational, aesthetic, and spiritual benefits; and
supporting services such as soil formation, photosynthesis, and nutrient cycling.

Figure A MA CONCEPTUAL FRAMEWORK OF INTERACTIONS AMONG BIODIVERSITY, ECOSYSTEM SERVICES, HUMAN WELL-BEING, AND DRIVERS OF CHANGE

Changes in drivers that indirectly affect biodiversity, such as population, technology, and lifestyle (upper right corner), can lead to changes in drivers directly affecting biodiversity, such as the catch of fish or the application of fertilizers to increase food production (lower right corner). These result in changes to biodiversity and ecosystems services (lower left corner), thereby affecting human well-being. These interactions can take place at more than one scale and can cross scales. For example, international demand for timber may lead to a regional loss of forest cover, which increases flood magnitude along a local stretch of a river. Similarly, the interactions can take place across different time scales. Actions can be taken either to respond to negative changes or to enhance positive changes at almost all points in this framework. Local scales refer to communities or ecosystems and regional scales refer to nations or biomes, all of which are nested within global-scale processes.



Marine and coastal systems within the MA context

Most of Earth (70.8% or 362 million km^2) is covered by oceans and major seas. Marine systems are highly dynamic and tightly connected through a network of surface and deep-water currents. The properties of the water form stratified layers, tides, and currents. Upwellings break this stratification by mixing layers and creating vertical and lateral heterogeneity within the ocean biome. The total global coastlines exceed 1.6 million kilometres, and coastal ecosystems occur in 123 countries around the world.

Coastal and marine ecosystems are among the most productive, yet threatened, ecosystems in the world; they include terrestrial ecosystems (e.g., sand dune systems), areas where freshwater and saltwater mix, nearshore coastal areas, and open ocean marine areas. In the context of the MA assessment, the ocean (or marine) and coastal realm has been divided into two major sets of systems: 'marine fisheries systems' and 'inshore coastal systems and coastal communities'. Marine systems are defined as waters from the low water mark (50m depth) to the high seas; and coastal systems are defined as <50m depth to the coastline and inland from the coastline to a maximum of 100 km or 50-metre elevation (whichever is closer to the sea). The MA defines the coastal zone as a narrower band of terrestrial area dominated by ocean influences of tides and marine aerosols, and defines a marine area where light penetrates throughout. (See MA *Condition and Trends* volume, section 19.1 [CT 19.1] for explanation of the definition.)

READER'S GUIDE

This report is a synthesis of the findings of the MA on marine and coastal ecosystems, taken from the global and sub-global assessments.

UNEP's Division of Early Warning and Assessment (DEWA) requested and supported this synthesis report to contribute to the dissemination of the information contained within the MA to decision-makers and a wide range of stakeholders of marine and coastal ecosystems. Six other synthesis reports have also been produced for different audiences: general overview, biodiversity (Convention on Biological Diversity), desertification (UN Convention to Combat Desertification), wetlands (Convention on Wetlands—Ramsar), the business sector, and the health sector. These synthesis reports along with the MA technical reports and sub-global assessments are available from www.MAweb.org.

This synthesis report sets out to provide answers to a series of questions that all stakeholders not just decision-makers may ask: what is at stake, what is the current status of marine and coastal ecosystems, why should we care if we lose marine and coastal ecosystems, and what can be done to ensure that marine and coastal ecosystems and services are conserved. A Summary is available at the beginning of the report. Key messages are highlighted in bold, while the use of italics refers to a key word to help direct the reader. A list of additional resources is provided in Appendix 3; a glossary of marine and coastal ecosystem terms is provided in Appendix 4; and Appendix 5 contains a list of acronyms and abbreviations. The reader should also note that while the MA uses the word 'system', this report has chosen to replace the word 'system' with 'ecosystem'. As a result of extensive interlinkages among ecosystems, the services they provide, and how we use them, it as been impossible to avoid a certain degree of duplication of text.

All information contained in this synthesis report is derived from chapters of the MA's four main assessment reports, and the report on *Ecosystems and Human Well-being; A Framework for Assessment*, which sets out the MA's conceptual framework (CF) and the approach and methodology adopted for the global assessment and relevant sub-global assessments. Reference to the chapters contained within these reports is presented in square brackets, which contain the number of the chapter and, where necessary, the section number, being referenced. These references are coded as follows: the MA Conceptual Framework [CF]; the *Condition and Trends* volume [CT]; the *Scenarios* volume [S]; the *Responses* volume [R]; the *Sub-global Assessments* volume [SG]; and various Synthesis Reports [SR], particularly the General SR, the Biodiversity SR, and the Wetlands SR. Where reference is made to the MA Summary for Decision-makers, this is coded as [SDM]. A list of chapters in the main MA volumes is provided in Appendix 2.

Throughout this report, dollar signs indicate U.S. dollars and measurements are metric (that is, billion equals a thousand million).

The wording of estimates of certainty, such as for the collective judgment of authors, observational evidence, modelling results, and theory examined is consistent with the MA and other synthesis reports: *very certain* (98% or greater probability), *high certainty* (85–98% probability), *medium certainty* (65–85% probability), *low certainty* (52–65% probability), and *very uncertain* (50–52% probability). For example, at least a *medium confidence* (near 65%) may exist for the comment 'desalinization could alter biodiversity'. Quantitative qualifiers on the amount of desalinization and the direction and severity of the biodiversity change must be added to the statement. When this is not appropriate, the standard MA qualitative scale for the level of scientific understanding is implemented: well established, established but incomplete, competing explanations, and speculative.

Following the synthesis of information from the MA chapters, scientific and policy experts within the marine and coastal field and selected MA authors provided review comments (a two-staged review process). To supplement the review process, the final draft of the synthesis report was made available at the meeting of the Global Marine Assessment in June 2005. All comments were taken into consideration in finalizing this synthesis report.

ACKNOWLEDGEMENTS

The Netherlands Ministry of Foreign Affairs, Development Cooperation, kindly provided financial support for the preparation and publication of this MA synthesis report on marine and coastal ecosystems.

We would like to acknowledge the review panel for providing comment on this synthesis report: Martin Adriaanse, Tundi Agardi, Margarita Astralaga, Charles Victor Barber, Kevern Cochrane, Nick Davidson, Ed Green, Stefan Hain, Tom Laughlin, Jackie McGlade, Elizabeth McLanahan, Edmund McManus, Rolph Payet, Henrique Pereira, Marjo Vierros, Sue Wells, and Christian Wild.

We would also like to further acknowledge all of the MA authors and review editors who contributed to this report through their contributions to the underlying assessment chapters, which this report is based upon.

We would also like to acknowledge the many donors that provided major financial support for the MA, particularly: Global Environment Facility, United Nations Foundation, David and Lucile Packard Foundation, World Bank, Consultative Group on International Agricultural Research, United Nations Environment Programme, Government of China, Ministry of Foreign Affairs of the Government of Norway, Kingdom of Saudi Arabia, and the Swedish International Biodiversity Programme. The full list of organizations that provided financial support to the MA is available at www.MAweb.org.

The synthesis editorial team would also like to thank Ryan Walker for his assistance in collating comments from reviewers.

KEY MESSAGES

- ***People are dependent on the ocean and coasts and their resources for their survival and well-being.*** *Marine and coastal ecosystems provide a wide range of services to human society, including food provision, natural shoreline protection against storms and floods, water quality maintenance, support of tourism and other cultural and spiritual benefits, and maintenance of the basic global life support systems. The effects of coastal degradation and a loss of these services are felt inland and often a long way from the coast.*

- ***The major drivers of change, degradation, or loss of marine and coastal ecosystems and services are mainly anthropogenic.*** *Important drivers of marine and coastal ecosystems include: population growth, land use change and habitat loss, overfishing and destructive fishing methods, illegal fishing, invasive species, climate change, subsidies, eutrophication, pollution, technology change, globalization, increased demand for food, and a shift in food preferences.*

- ***Marine and coastal ecosystems are among the most productive and provide a range of social and economic benefit to humans.*** *More than one third of the world's population live in coastal areas and small islands that make up just over 4% of Earth's total land area. Fisheries and fish products provide direct employment to 38 million people. Coastal tourism is one of the fastest growing sectors of global tourism and provides employment for many people and generates local incomes. For example, reef-based tourism generates over $1.2 billion annually in the Florida Keys (of the United States) alone.*

- ***Most services derived from marine and coastal ecosystems are being degraded and used unsustainably and therefore are deteriorating faster than other ecosystems.*** *Unsustainable use of services can result in threatened food security for coastal communities due to overexploited fish stocks; loss of habitat that in turn causes damage to the thriving tourism industry; health impacts through increasing loads of waste released into coastal waters; and vulnerability of coastal communities to natural and human-induced disasters. The MA scenarios forecast a great risk of collapse of all major fish stocks and climate change-induced sea-level rise (with mean value of 0.5–0.7 m).*

- ***The highly threatened nature of marine and coastal ecosystems and the demand for their services highlight the need for a local, regional, and global response.*** *A range of options exists to respond to the challenges that the degradation of ecosystems is posing (for example, implementation of regional and global agreements or stakeholder participation and capacity development). Addressing uncertainties and elaborating trade-offs provide useful mechanisms for operational responses.*

- ***Trade-offs in meeting the Millennium Development Goals and other international commitments are inevitable.*** *However, implementing the established ecosystem-based approaches (for example, integrated coastal management) adopted by the CBD, the Convention on Wetlands (Ramsar), and FAO, amongst others, as well as existing local and regional legislation, policy, and guidelines on the future condition of marine and coastal ecosystem services could be substantially improved by balancing economic development, ecosystem preservation, and human well-being objectives.*

- ***Improved capacity to predict the consequences of change of drivers in marine and coastal ecosystems would aid decision-making at all levels.*** *Long-term and large-area ecological processes are particularly poorly understood; and yet, in a number of areas, issues and well-defined policies have not been sufficiently developed. Monitoring of biodiversity change at the ecosystem and species level is essential.*

SUMMARY

What is the current status of marine and coastal ecosystems and their services?

Key Message # 1 *People are dependent on the ocean and coasts and their resources for their survival and well-being. Marine and coastal ecosystems provide a wide range of services to human society, including food provision, natural shoreline protection against storms and floods, water quality maintenance, support of tourism and other cultural and spiritual benefits, and maintenance of the basic global life support systems. The effects of coastal degradation and a loss of these services are felt inland and often a long way from the coast.*

Coastal and marine ecosystems are amongst the most productive ecosystems in the world and provide many services to human society; however, many of these ecosystems have become degraded. Food provisioning in the form of *fisheries* catch is one of the most important services derived from coastal and marine ecosystems. With more than a billion people relying on fish as their main or sole source of animal protein, fisheries in developing countries are a particularly important source of protein. Fisheries and fish products provide direct employment to 38 million people, with a further 162 million people indirectly involved in the fisheries industry (FAO 2004). The state of industrial fisheries is of concern as many people depend on their existence for food and employment, with many fisheries being overexploited. (See Figure 1.) *Aquaculture* is the fastest-growing food-producing sector, accounting for 30% of total fish consumption.

Other provisioning services from these ecosystems include *curios and ornamentals* for the aquarium trade, *building materials* (for example, for boat construction and house construction), and *bioprospecting* (the exploration of biodiversity for new biological resources, such as pharmaceuticals).

The seas and coasts around the world are of great spiritual importance to many people, providing cultural and spiritual services. Coastal *tourism* is one of the fastest growing sectors of global tourism and is an essential component of the economies of many small island developing states (SIDS). Much of the economic value of coral reefs is generated from nature-based and dive tourism, with net benefits estimated at nearly $30 billion annually. The cultures of many peoples are closely connected to coasts and oceans, and *traditional knowledge* has become an integral part of the dynamics of island and coastal ecosystems and their management. In addition, coastal and marine habitats are areas of research and efforts in *education and public awareness*.

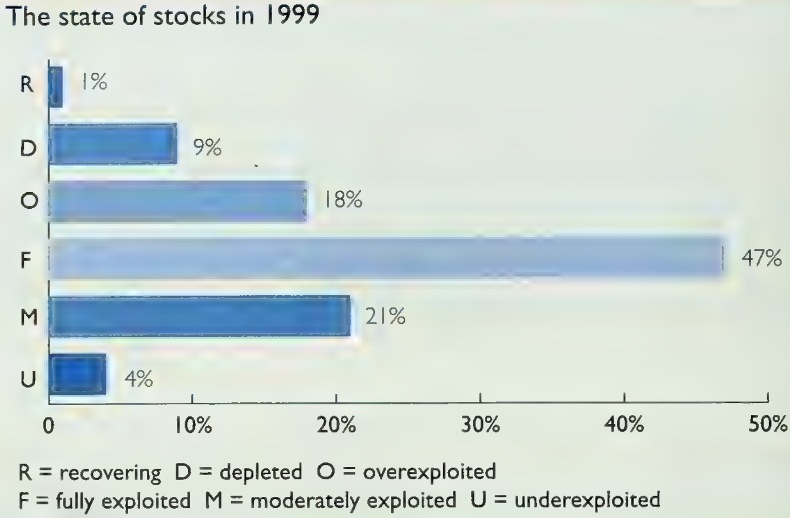
Marine and coastal ecosystems provide supporting services in the form of a wide range of *habitats*. Estuaries, mangroves, lagoons, seagrasses, and kelp forests serve as nurseries for both inshore and offshore fish and other species, many of which are commercially significant. Other habitats such as beaches, dunes, saltmarshes, estuaries, and mudflats play an important role in the life cycle of, for example, fish, shellfish, and migratory birds. Marine and coastal ecosystems play an important role in *photosynthesis* and *productivity*. Through mixing nutrients from upstream and tidal sources, estuaries are one of the most *fertile coastal environments*.

Box 1 SERVICES PROVIDED BY COASTAL AND MARINE ECOSYSTEMS

The MA recognizes a range of benefits that people obtain from coastal and marine ecosystems. These ecosystem services include:
provisioning services such as food, water, timber, and fibre;
regulating services such as the regulation of climate, floods, disease, wastes, and water quality;
cultural services such as recreational, aesthetic, and spiritual benefits; and
supporting services such as soil formation, photosynthesis, and nutrient cycling.

Figure 1 THE STATE OF FISH STOCKS IN 1999 [CT 4.5.1.5, Figure 4.21]

Ecosystems such as mangroves, seagrasses, and mudflats provide key **regulating services** through *shoreline stabilization, protection from floods and soil erosion, processing pollutants*, and *stabilizing land* in the face of changing sea levels by trapping sediments and buffering land from storms. Marine systems play significant roles in *climate regulation* and *nutrient cycling*. CO_2 is continuously exchanged between the atmosphere and ocean; it dissolves in surface waters and is then transported into the deep ocean.



What are the drivers of change in marine and coastal ecosystems?

Key Message # 2 *The major drivers of change, degradation, or loss of marine and coastal ecosystems and services are mainly anthropogenic. Important drivers of marine and coastal ecosystems include: population growth, land use change and habitat loss, overfishing and destructive fishing methods, illegal fishing, invasive species, climate change, subsidies, eutrophication, pollution, technology change, globalization, increased demand for food, and a shift in food preferences.*

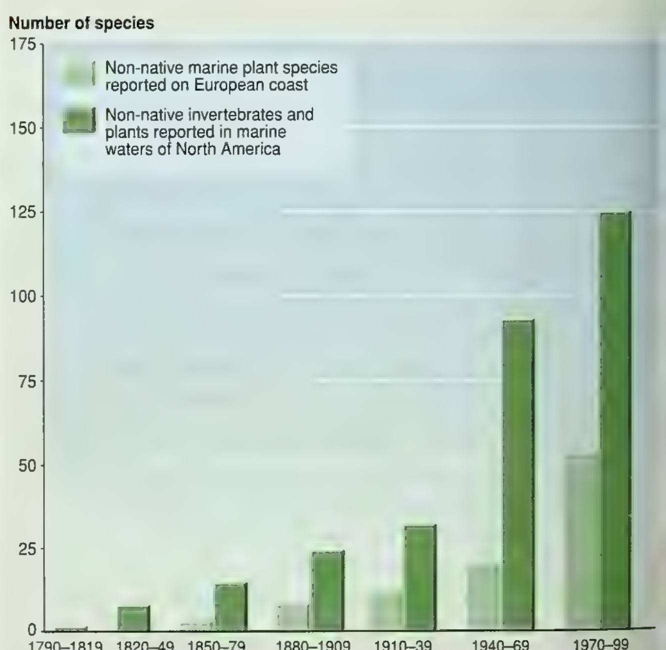
Within the coastal population, 71% live within 50 kilometres of estuaries, and in tropical regions, settlements are concentrated near mangroves and coral reefs. These marine and coastal habitats have been degraded or transformed, mainly through anthropogenic impacts.

In particular, coastal habitats have been affected by *land use change and habitat loss*, resulting in severe negative impacts on ecosystems and species. Excessive amounts of sedimentation and agricultural practices upstream have resulted in degradation of estuaries. Mangroves have been converted to allow for coastal zone development, aquaculture, and agriculture. Mudflats, saltmarshes, mangroves, and seagrasses are commonly destroyed for port and other industrial and infrastructure development or maintenance dredging. Coral reefs suffer from destructive fishing, use of coral for road and building construction, collection for the ornamental trade, sedimentation, and dumping of pollutants.

Overfishing and destructive fishing methods, such as some forms of bottom trawling (for example, the use of heavy gear

Figure 2 GROWTH IN NUMBER OF MARINE SPECIES INTRODUCTIONS

Number of new records of established non-native invertebrate and algae species reported in marine waters of North America, shown by date of first record, and number of new records of non-native marine plant species reported on the European coast, by date of first record [General SR, Figure 1.7].



Source: Millennium Ecosystem Assessment

on sensitive substrates), dredging, and the use of explosives and fish poisons such as cyanide impact on marine ecosystems by physically altering or destroying the systems or changing community structure and altering trophic and other interactions between ecosystem components. The global decline of commercially important fish stocks is well documented, with many fishery resources being overexploited. *Subsidies* are amongst the most powerful drivers of overfishing. The value of fisheries subsidies as a percentage of the gross value of production in the OECD area was about 20% in 2002. The development and operation of *aquaculture* often has serious environmental impacts, concerning habitat loss (for example, removal of mangroves), salinization of adjacent lands, releasing effluents into the surrounding waters, use of high quality fishmeal to produce fish, and infectious diseases being spread into wild fish populations.

Invasive species are expected to grow in importance as a driver of ecosystem change in marine and coastal areas. (See Figure 2.) A major source of marine introductions of non-native species is through the release of ballast water from ships.

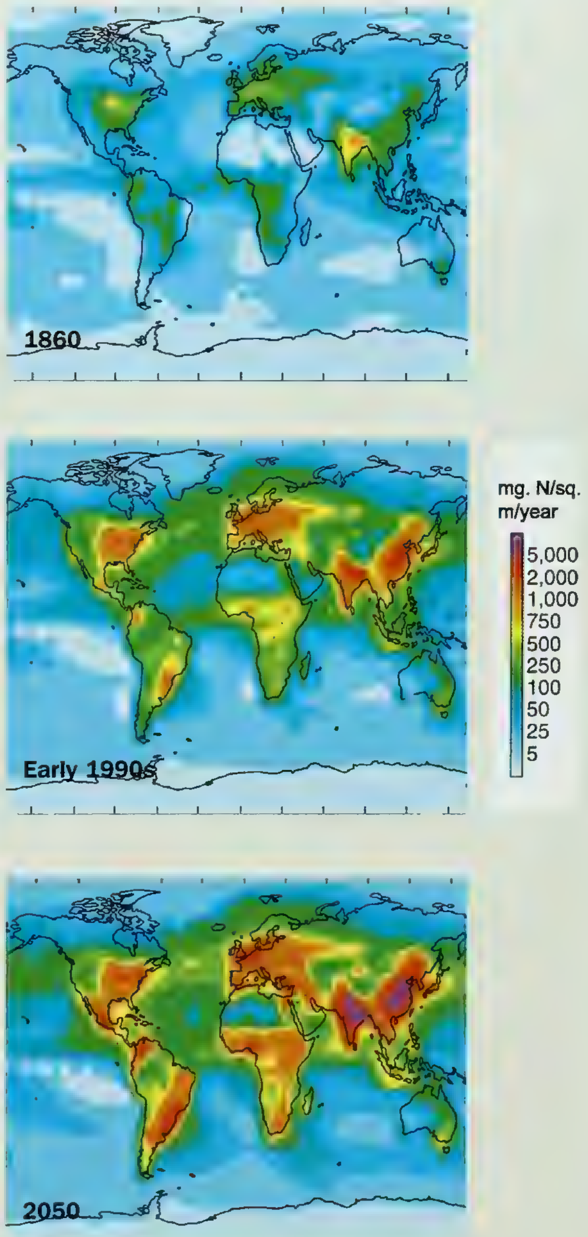
Increased *nutrient loading* from agricultural run-off, sewage, and burning of fossil fuels is causing widespread *eutrophication* of coastal and marine ecosystems. (See Figure 3.) For example, this nutrient pollution stimulates algal growth and reduces the quality of light in the water column, leading to a depletion of oxygen, which reduces the ability of other marine organisms to persist. This is a particular problem near centres of human population where *pollution* through the release of: often untreated human waste, pollutants such as persistent organic pollutants, and toxic waste contribute to the problems.

Climate change is increasingly becoming one of the dominant drivers of change in vulnerable habitats such as mangroves, coral reefs, and coastal wetlands, which are especially at risk from resulting sea-level rises and increased storm events. Coral reefs are vulnerable to climate-change-induced bleaching. It has been suggested by many that coral mortality through global warming will reduce the major coral reefs substantially in a very short time frame, with one estimate even suggesting that all current coral reefs could disappear by 2040 due to warming sea temperatures.

A number of *indirect drivers* of change in marine and coastal ecosystem have been identified. *Technology* change contributes to overexploitation of fish stocks. The same is true for the shift in food preferences and globalization, with some marine products becoming a luxury food, driving up demand and fish prices. *Illegal fishing* also contributes to overexploitation and is particularly due to lack of surveillance, enforcement, and monitoring. Also, *demographic developments* in coastal zones drive changes in ecosystems, with coastal population densities being nearly three times that of inland areas. An important ecosystem service, *tourism* can also have a negative impact upon marine and coastal areas, for example through people walking on coral reefs at low tide.

Figure 3 ESTIMATED TOTAL REACTIVE NITROGEN DEPOSITION FROM THE ATMOSPHERE (WET AND DRY) IN 1860, EARLY 1990S, AND PROJECTED FOR 2050 (milligrams of nitrogen per square metre per year)

Atmospheric deposition currently accounts for roughly 12% of the reactive nitrogen entering terrestrial and coastal marine ecosystems globally, although in some regions, atmospheric deposition accounts for a higher percentage (about 33% in the United States) [R9, Figure 9.2].



Source: Galloway et al. 2004

Why should we care about the loss or degradation of marine and coastal ecosystems and their services?

Key Message # 3 *Marine and coastal ecosystems are among the most productive and provide a range of social and economic benefits to humans. More than one third of the world's population live in coastal areas and small islands that make up just over 4% of Earth's total land area. Fisheries and fish products provide direct employment to 38 million people. Coastal tourism is one of the fastest growing sectors of global tourism and provides employment for many people and generates local incomes. For example, reef-based tourism generates over $1.2 billion annually in the Florida Keys alone.*

Key Message # 4 *Most services derived from marine and coastal ecosystems are being degraded and used unsustainably and therefore are deteriorating faster than other ecosystems. Unsustainable use of services can result in threatened food security for coastal communities due to overexploited fish stocks, loss of habitat resulting in damage to the thriving tourism industry, health impacts through increasing loads of waste released into coastal waters, to vulnerability of coastal communities to natural and human-induced disasters. The MA scenarios forecast a great risk of collapse of all major fish stocks, and climate-change-induced sea-level rise (with mean value of 0.5–0.7m).*

Human well-being is closely linked to the availability of the services that marine and coastal ecosystems provide. The degradation and loss of many of these ecosystems therefore gives reason for concern. The decreasing fish stocks threaten *food security* in many coastal areas but have implications far beyond. For example, the decreased availability of fish for subsistence in West Africa has driven an increase in illegal bush meat trade, which in turn threatens many species and is thought to contribute to outbreaks of primate-borne and other viruses in human populations.

Fisheries and tourism are major sources of employment, often in developing countries. *Loss of habitat* and *degrading stocks* (see Figure 4) could heavily *impact on employment.* The massive coral bleaching in 1998 is expected to result in an estimated long-term damage over 20 years of between $600 million and $8 billion with costs incurred through declines in tourism-generated income and employment, decreases in fish productivity, and loss of reefs functioning as a protective barrier.

Human communities are at risk from the health implications of degraded ecosystems, with waterborne *diseases* such as cholera being on the rise in coastal countries, which can be related to ciguatera poisoning associated with algal blooms. Severe health problems are caused by pollution of nearshore waters where people consume fish or other marine products contaminated by heavy metals, PCBs, and other toxins.

Coastal communities are at risk from *natural* (for example, hurricanes, cyclones, tsunamis, and floods) and *human-induced disasters.* Losses of habitats such as mangrove forests threaten the safety of people in 118 coastal countries. Mangroves and saltmarshes not only serve as a buffer from storm damage, but also provide areas for fish spawning and nursery areas for both inshore and offshore capture fisheries; they also absorb heavy metals and other toxic substances.

What can we do about the loss of marine and coastal ecosystems and their services?

Key Message # 5 *The highly threatened nature of marine and coastal ecosystems and the demand for their services highlight the need for a local, regional, and global response. A range of options exists to respond to the challenges that the degradation of ecosystems is posing (for example, implementation of regional and global agreements or stakeholder participation and capacity development). Addressing uncertainties and elaborating trade-offs provide useful mechanisms for operational responses.*

Key Message # 6 *Trade-offs in meeting the Millennium Development Goals and other international commitments are inevitable. However, implementing the established ecosystem-based approaches (for example, integrated coastal management) adopted by the CBD, the Convention on Wetlands (Ramsar), and FAO, amongst others, as well as existing local and regional legislation, policy, and guidelines on the future condition of marine and coastal ecosystem services could be substantially improved by balancing economic development, ecosystem preservation, and human well-being objectives.*

The MA has identified a number of major options for responding to the challenges posed by the degradation of the services provided by marine and coastal ecosystems. These can be divided into operational and specific responses. (See Table 1.)

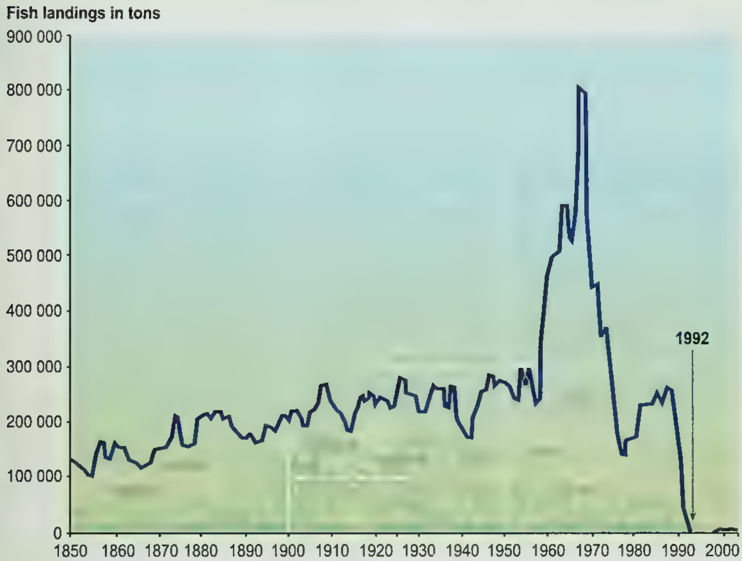
Implementing responses necessitates recognizing that trade-offs and uncertainties will need to be considered along with addressing the interests of stakeholders. To select the best response, decision-makers should take into consideration: available information; implication regarding procedure and efficiency; effectiveness in producing required results; stakeholder participation and transparency of outcomes; values and beliefs of stakeholders; uncertainties; and cross-scale effects.

A range of tools exists that support the application of policy options. They include *multi-criteria analyses, scenarios, environmental impact assessment, and economic valuation.* The last has been successful in demonstrating the value of protecting natural coastal wetlands over their conversion for commercial use.

It is important that existing global, regional, and national legislation, policy, and guidelines are implemented and enforced.

Figure 4 COLLAPSE OF ATLANTIC COD STOCKS OFF THE EAST COAST OF NEWFOUNDLAND IN 1992

This collapse forced the closure of the fishery after hundreds of years of exploitation. Until the late 1950s, the fishery was exploited by migratory seasonal fleets and resident inshore small-scale fishers. From the late 1950s, offshore bottom trawlers began exploiting the deeper part of the stock, leading to a large catch increase and a strong decline in the underlying biomass. Internationally agreed quotas in the early 1970s and, following the declaration by Canada of an Exclusive Fishing Zone in 1977, national quota systems ultimately failed to arrest and reverse the decline. The stock collapsed to extremely low levels in the late 1980s and early 1990s, and a moratorium on commercial fishing was declared in June 1992. A small commercial inshore fishery was reintroduced in 1998, but catch rates declined and the fishery was closed indefinitely in 2003 [General SR, Figure 3.4].



Source: Millennium Ecosystem Assessment

What are the major knowledge gaps?

Key Message # 7 *Improved capacity to predict the consequences of change of drivers in marine and coastal ecosystems would aid decision-making at all levels. Long-term and large-area ecological processes are particularly poorly understood; and yet, in a number of areas, issues and well-defined policies have not been sufficiently developed. Monitoring of biodiversity change at the ecosystem and species level is essential.*

Long-term and large-area ecological processes are poorly understood in marine ecosystems. This lack of knowledge particularly refers to the oceanic nitrogen cycle, the El Niño/Southern Oscillation, basic data on the past and current extent of marine and coastal habitats, the variability of marine fish stocks, and the understanding of marine biodiversity in general.

Most existing *biological measures* such as indicators do not reflect many important aspects of marine and coastal biodiversity, especially those that are significant for the delivery of ecosystem services.

The information available to assess the *consequences for human well-being of changes in ecosystem services* is still limited, not least due to the nonlinearity of the relationship between human well-being and ecosystem services.

Policy responses would benefit from addressing a range of uncertainties, including the understanding of the benefits and costs of marine protected areas and the outcomes for ecosystem conditions of integrated coastal management and integrated coastal zone management. Improved knowledge would enable better-defined trade-offs.

Policies are currently weak or widely lacking, particularly in areas such as the impacts from agriculture in marine and coastal areas; addressing new and emerging issues (for example, off-shore wind farms); compliance relating to high-seas initiatives and agreements; and genetic resources.

Existing policy and legislation often still lack consistent implementation and enforcement because funding, political will, and human resources are lacking.

Table 3 OPERATIONAL AND SPECIFIC RESPONSE OPTIONS AVAILABLE TO ADDRESS THE ALTERATION AND LOSS OF MARINE AND COASTAL ECOSYSTEMS AND THEIR SERVICES

RESPONSE	Effective	<Effectiveness> Promising	Problematic	Type of Responses	Required Actors
Operational responses					
Stakeholder participation in decision-making	X			I, S	GN, GL, NGO, B, C, R
Capacity development	X			I	GN, GL, NGO, C, R
Communication, education, public awareness	X			S	GN, GL, NGO, C
Alternative income-generating activities		X	X	E S	GL, NGO, C
Monitoring	X	X		I, T, K	GI, GN, GL, NGO, C, R
Addressing uncertainty		X	X	I, K	GN, GL, C, R
Trade-off analysis		X	X	I, E	GN, GL, C
Specific responses					
Applying international/regional mechanisms		X	X	I	GI, GN
Large marine ecosystems		X	X	I	GI, GN
Integrated coastal management and planning	X	X		I, S	GN, GL, C R
Marine protected areas	X	X		I, S	GN, GL, NGO, C
Coastal protection	X	X	X	T	GI, GN, B
Management of nutrient pollution—runoff, fossil fuel combustion	X		X	I, T	GI, GN, GL
Waste management—household and industrial sewage	X		X	I, E, S, T	GI, GN, GL
Geo-engineering—CO_2 sequestration			X	I, T	GI, GN, B
Economic interventions: market-based instruments		X	X	E	GN, B
Fisheries management		X	X	I	GN, GL, B, C
Aquaculture management		X	X	I	GN, GL, B, C

Key to codings
Type of response
I = institutional and legal
E = economic and incentives
S = social and behavioural
T = technology
K = knowledge

Required actors
GI = government at a international level
GN = national government
GL = local government
B = business/industry sector
NGO = civil society including non-governmental organizations
C = community-based and indigenous people's organizations
R = research institutions

What Is at Stake?

Humankind depends on the oceans and coasts and their resources for its survival. Ocean circulation is largely driven by climate, and it determines not only the distribution and abundance of marine living resources but also the transfer, through evaporation and rainfall, of freshwater to the land. Changes in human activities at the global scale are causing climate warming, which is significantly altering the occurrence of these resources on which people rely. The warming is influencing ocean circulation and latitudinal transport of heat, causing sea level to rise and endangering the long-term security of people living in low-lying coastal areas. Rising sea-surface temperatures can also threaten the survival of coral reefs.

Marine living resources are additionally severely impoverished by many drivers, including the growth in industrial-scale fishing. Humankind derives 16% of its animal protein from the sea, but by 1999, 27% of global marine fish stocks had been exhausted or were overexploited. Continuing overexploitation is jeopardizing food security and the livelihoods of hundreds of millions of people.

Coastal populations in particular are affected by these changes. More than one third of the world's population lives in coastal areas and small islands, which together make up just 4% of the total land area, and this population is increasing rapidly. In addition to the impacts of global change, the expansion of development activities in coastal areas and their related catchments is increasingly causing the loss of habitats and degrading the services that have been available to humans from the coastal and marine ecosystems. Pollution from agricultural, industrial, and urban sources far and near is creating ocean dead zones and costing $16 billion per year, largely in response to resulting human health problems. People at all levels in society can help to reverse these trends and improve societal well-being. In particular, decision-makers in government, industry, and civil society must raise awareness and instigate appropriate and cooperative response actions. Changes ranging from adaptation in farming methods through to the removal of fishing subsidies will have profound remedial effects. Arresting the further degradation of coastal and marine ecosystem resources for the benefit of both present and future generations is an urgent imperative to ensure greater food security, lower health impacts, and reduce poverty (and ultimately meet the Millennium Development Goals).

SYNTHESIS

1 *What is the current status of marine and coastal ecosystems and their services?*

- Marine and coastal ecosystems provide many services to human society, including food and other goods, shoreline protection, water quality maintenance, waste treatment, support of tourism and other cultural benefits, and maintenance of the basic global life support systems.
- The provision of these services is threatened by the worldwide degradation of marine and coastal ecosystems. Fisheries are in global decline. Coastal habitats have been modified and lost, and in many cases the rate of degradation is increasing. Habitat loss and modification result in a loss of ecosystem services and also threaten biodiversity.
- There are major gaps in our knowledge of marine and coastal ecosystems and in methodology to assess and manage them. Data and knowledge gaps include inadequate understanding of the marine nitrogen and other nutrient cycles and of the El Nino/Southern Oscillation (ENSO). The inadequacy of data on the extent and status of many marine and coastal ecosystems makes it difficult to estimate the extent of past change and future trends. Inadequate understanding of variability in fish stocks increases the risk of major stock collapses. Gaps in methodology include inadequate development of multi-species fisheries management tools and the inadequate development of agreed biodiversity indicators.

Introduction

The marine chapter [CT 18] of the MA focuses largely on the condition and trends of fisheries resources (including nearshore and deep-seas) and the impact of human use. The MA touches only briefly on other activities impacting marine ecosystems such as tourism, mining (for example, gold, diamonds, and tin), and gas and oil. The reasons for this focus are the huge impact of fishing over the last 50 years and inadequate information about other aspects of offshore systems. Figure 1.1 shows the classification used in the MA and this report of the world's oceans. The coastal chapter [CT 19] of the MA focuses on nearshore habitats and significant associated flora and fauna. Figure 1.2 illustrates the spatial definition of marine and coastal ecosystems within the MA.

Ecosystem Services from Marine and Coastal Ecosystems

The assessment focuses on the linkages between ecosystems and human well-being and in particular on 'ecosystem services' (the benefits that people obtain from ecosystems). An ecosystem is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Maintaining biodiversity underpins all ecosystem services.

Coastal and marine ecosystems provide a wide range of services to human beings. These include *provisioning services* such as supply of food, fuel wood, energy resources, natural products, and bioprospecting; *regulating services*, such as shoreline stabilization, flood prevention, storm protection, climate regulation, hydrological services, nutrient regulation, carbon sequestration, detoxification of polluted waters, and waste disposal; *cultural and amenity services* such as culture, tourism, and recreation; and *supporting services* such as habitat provision, nutrient cycling, primary productivity, and soil formation. These services are of high value not only to local communities living in the coastal zone (especially in developing countries) but also to national economies and global trade [CT 19.3.2]. Table 1.1 provides examples of ecosystem services provided by various marine and coastal habitats.

Provisioning Services

Provisioning services are the products people obtain from ecosystems, such as food, fuel, timber, fibre, building materials,

medicines, genetic and ornamental resources. Coastal and marine ecosystems provide a wide range of these services; they are among the most productive ecosystems in the world [CT 23.3.3].

Fisheries as Food Provisioning in Marine and Coastal Ecosystems

Food provisioning in the form of fisheries catch is one of the most important services derived from all coastal and marine ecosystems. For example, mangroves are important in supporting fisheries due to their function as fish nurseries. Fisheries yields in waters adjacent to mangroves tend to be high [CT 19.2.1.2]. Coral reef-based fisheries are also valuable, as they are an important source of fisheries products for coastal residents, tourists, and export markets. In developing countries, coral reefs contribute about one quarter of the annual total fish catch, providing food to about one billion people in Asia alone [CT 19.3.2]. Other ecosystems such as rocky intertidal, nearshore mudflats, deltas, kelp forests, and beaches and dunes also provide food.

Overall, coastal and marine fisheries landings averaged 82.4 million tonnes per year during 1991-2000, with a stagnating or declining trend now largely attributed to overfishing [CT 18.1]. Certain areas of the ocean are more productive than others. The coastal biome produces approximately 53% (in 2001) of the world's marine catches [CT 18.2.2]. The coastal biome is also the most impacted by human activities. Coral reef fisheries in this biome, for example are overexploited in many reef systems around the world. Table 1.2 summarizes the status of recognized costal habitats.

The mid-twentieth century saw the rapid expansion of fishing fleets throughout the world, and with it, an increase in the volume of fish landed. (See Figure 1.3.) This trend continued until the late 1980s, when global marine landings reached slightly over 80 million tonnes per year, then either stagnated or began to slowly decline. However, regional landings peaked at different times throughout the world, which in part masked the decline of many fisheries [CT 18.2.1].

With fleets now targeting the more abundant fish at lower trophic levels (called 'fishing down the food chain'), it would be expected that global catches would be increasing, rather than, as is actually occurring, stagnating or decreasing. (See Box 1.1 and Figure 1.4.) The decline in catches is largely due to the loss of large, slow-growing predators at high trophic levels; these are gradually being replaced, in global landings, by smaller, shorter-lived fish, at lower trophic levels. Until a few decades ago, depth and distance from coasts protected much of the deep ocean fauna from the effect of fishing. However, fleets now fish further offshore and in deeper water with greater precision and efficiency, compromising areas that acted as refuges for the spawning of many species of commercial interest to both industrial and artisanal fleets [CT 18.2.1]. (See Figure 1.5.)

Of the four ocean areas—the Atlantic, the Pacific, the Indian, and the Mediterranean—the Atlantic was the first to be fully exploited and, eventually, overfished. This process is about to be completed in the Pacific. There still seems to be some minor

Figure 1.1 CLASSIFICATION OF THE WORLD'S OCEANS' IDENTIFIED FOUR 'BIOMES' (POLAR, WESTERLIES, TRADE-WINDS, AND COASTAL BOUNDARY)

A black border around each continent indicates the coastal boundary. Each of these biomes is subdivided into biogeographical provinces (BGP) [CT 18.1, Figure 18.1].

Figure 1.2 DEFINITION OF THE SPATIAL OCCURRENCE OF MARINE AND COASTAL ECOSYSTEMS WITHIN THE MA [CT 19.1, Figure 19.1]d i

potential for expansion of sustainable capture fisheries in the Indian Ocean and—against expectations—in the Mediterranean, although this may be due to environmental changes including eutrophication [CT 18.2.2].

Although the global decline of commercially important fish stocks or populations is relatively well documented, little is known about the ecology of the majority of fish populations. Most industrial fisheries are either fully or overexploited. (See Figure 1.6.) Twenty-eight percent of the fish stocks under various assessment programmes have declined to levels lower than that at which a maximum sustainable yield (MSY) can be taken, and a further 47% require stringent management (which may or may not already be in place) to prevent their declining into a similar situation. Thus 75% of the assessed fish stocks need management to prevent further declines and/or to bring about recovery in spawning stock biomass. Conversely, 72% of the stocks are still capable of producing a maximum sustainable yield. Further, trend analysis since 1974 shows the percentage of underexploited stocks has declined steadily, while the proportion of stocks exploited beyond MSY levels have increased steadily over this time period (see section 1.4.2 for gaps in this methodology). If these data are representative of fisheries as a whole, they indicate an overall declining trend in spawning-stock biomass for commercially important fish species over the last 30 years [CT 4.4.1.5].

During the last four decades, the rise in per capita fish consumption has been quite rapid for the world as a whole. Table 1.3 shows fish consumption and production over the last half of the 1990s. By 2000, average per capita fish supply reached around 16 kg per year, but growth rates are slowing [CT 8.2.2.3] and average annual per capita fish supply in 2004 only increased to 16.2 kg (FAO 2004).

Continuation of current fisheries trends, including the build-up of fishing capacities, poses a serious risk of losing more fisheries. In numerous cases, however, responses to fisheries management problems have mitigated or reversed the impact of fisheries. For example, the introduction of community-based management of reef areas in the Philippines has resulted in increased fish landings that ultimately improved the well-being of those communities. Increasingly effective enforcement measures for Namibian fisheries and the nationalization of the fishery sector appear to be contributing to improving socioeconomic conditions for many coastal communities. In general, relatively small and often single-species fisheries can be restored, as has occurred in the Peruvian hake (*Merluccius gayi peruanus*) fishery [18.7.1].

Aquaculture as Food Provisioning in Marine and Coastal Ecosystems

Growth in demand for fish as a food source is being met in part by aquaculture, which now accounts for 30% of total fish consumption. According to FAO statistics, the contribution of (freshwater and marine) aquaculture to global supplies of fish, crustaceans, and molluscs continues to grow, increasing from 3.9% of total global production weight in 1970 to 27.3% in 2000. Aquaculture is growing more rapidly than all other animal food-producing sectors [CT 26.2.3] and was worth $57 billion in 2000 [CT 18.1]. Demands for coastal aquaculture have been on the rise, increasing the price of some fish (for example, salmon) and the need to supply cheap protein, but the

TABLE 1.1 EXAMPLES OF ECOSYSTEM SERVICES PROVIDED BY DIFFERENT MARINE AND COASTAL HABITATS
(X indicates the habitat provides a significant amount of the service)

ECOSYSTEM SERVICES	Coastal									Marine		
	Estuaries and marshes	Mangroves	Lagoon and salt ponds	Intertidal	Kelp	Rock and shell reefs	Seagrass	Coral reefs	Inner shelf	Outer shelves edges slopes	Seamounts & mid-ocean ridges	Deep sea and central gyres
Biodiversity	X	X	X	X	X	X	X	X	X	X	X	X
Provisioning services												
Food	X	X	X	X	X	X	X	X		X	X	X
Fibre, timber, fuel	X	X	X						X	X		X
Medicines, other resources	X	X	X		X			X	X			
Regulating services												
Biological regulation	X	X	X	X		X		X				
Freshwater storage and retention	X		X									
Hydrological balance	X		X									
Atmospheric and climate regulation	X	X	X	X		X	X	X	X	X		X
Human disease control	X	X	X	X		X	X	X				
Waste processing	X	X	X				X	X				
Flood/storm protection	X	X	X	X	X	X	X	X				
Erosion control	X	X	X				X	X				
Cultural services												
Cultural and amenity	X	X	X	X	X	X	X	X	X			
Recreational	X	X	X	X	X			X				
Aesthetics	X		X	X				X				
Education and research	X	X	X	X	X	X	X	X	X	X	X	X
Supporting services												
Biochemical	X	X			X			X				
Nutrient cycling and fertility	X	X	X	X	X	X		X	X	X	X	X

Table 1.2 SUMMARY OF STATUS OF COASTAL HABITAT TYPES
(many of the habitat types included in this table often overlap in their natural state)

HABITAT TYPE	STATUS	COMMENTS
Estuaries	Substantial loss	e.g., < 10% natural coastal wetlands remain in California, with over half of U.S. coastal wetlands substantially altered
Mangroves	35% loss in last two decades for countries with data	>80% loss in some countries
Coral reefs	20% severely damaged and unlikely to recover (2004 estimate); 70% are destroyed, critical, or threatened (2004 estimate)	Caribbean and Southeast Asia most degraded
Intertidal habitats and deltas	Substantial degradation	37% loss on Yellow Sea coast of China since 1950; 43% loss in South Korea since 1918
Beaches and dunes	Complete loss or degradation in many places	
Seagrass beds	Major losses in Mediterranean, Florida, and Australia	Degradation expected to accelerate, especially in Southeast Asia and the Caribbean
Kelp forests	Probably none exists in a natural condition	
Saltmarshes or ponds	Massive alteration and loss	
Semi-enclosed seas	Becoming highly degraded	
Other bottom communities	Severely impacted by effects of fishing	Strong evidence for impacts on ecosystem function and resilience

doubling of aquaculture production in the last 10 years has also driven habitat loss, overexploitation of fisheries for fishmeal and fish oil, and pollution [CT 19, Main Messages].

Export fisheries have also influenced the aquaculture industry, especially for salmon and shrimp, which are bred to meet the demands from industrial countries for luxury high-value seafood. Increased export demand often leads to expansion of aquaculture practices. In 1998, salmon (much of it farmed) was the leading fish export commodity of the EU. Countries (such as Thailand) that are the leading producers of shrimp (much of it from aquaculture) are also often the leading exporters [CT 18.3.7].

Coastal areas provide the foundation for the mariculture (marine aquaculture) industry, which uses coastal space or relies on wild stock to produce valuable fisheries products, from tiger prawns to bluefin tuna. Human reliance on farmed fish and shellfish is significant and growing. Global annual per capita consumption of seafood averages 16 kilograms, and one third of that supply currently comes from aquaculture. Globally, aquaculture production rates have doubled in weight and value from 1989 to 1998. Much of that growth has occurred in the shrimp and salmon farming industries [CT 19.3.2.1]. Aquaculture on its own will not stem the overexploitation of wild capture fisheries.

Freshwater aquaculture is generally considered more environmentally sustainable than brackish water and marine aquaculture because of its much greater reliance on omnivore or herbivore species. Carnivores are found in higher trophic levels and their culture involves the use of formulated diets containing a high percentage of fishmeal (in some cases as much as 40% of

Figure 1.3 ESTIMATED GLOBAL FISH CATCHES (1950–2001) BY TARGET GROUP (TOP) AND BY BIOME (BOTTOM)
Includes adjustment for overreporting [CT 18, Figure 18.3].

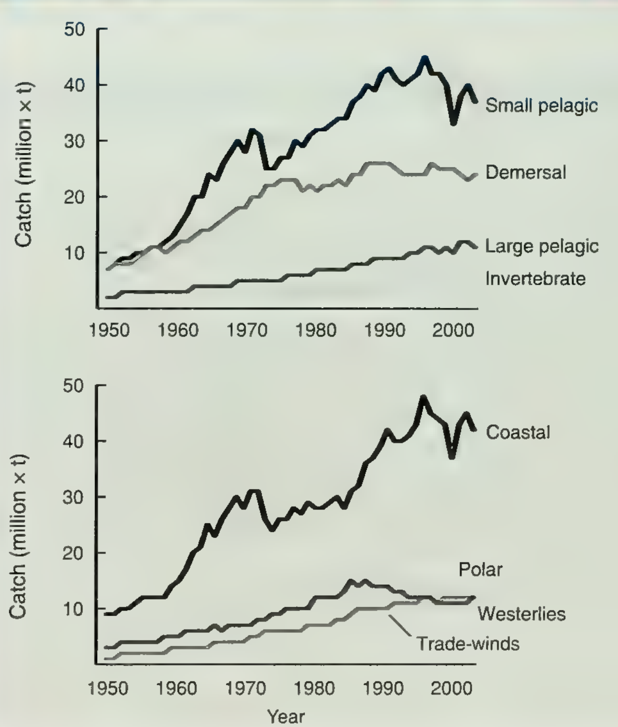


Figure 1.4 TROPHIC LEVEL CHANGE (1950–2000)

Changes in trophic levels of global and regional catches are considered a better reflection of trends in fisheries than the proportion of fish stocks that are reported as depleted, overexploited, fully exploited, and moderately exploited. Focusing on trophic levels ensures that an overestimation of fisheries does not occur [CT 18.2.1, Figure 18.4].

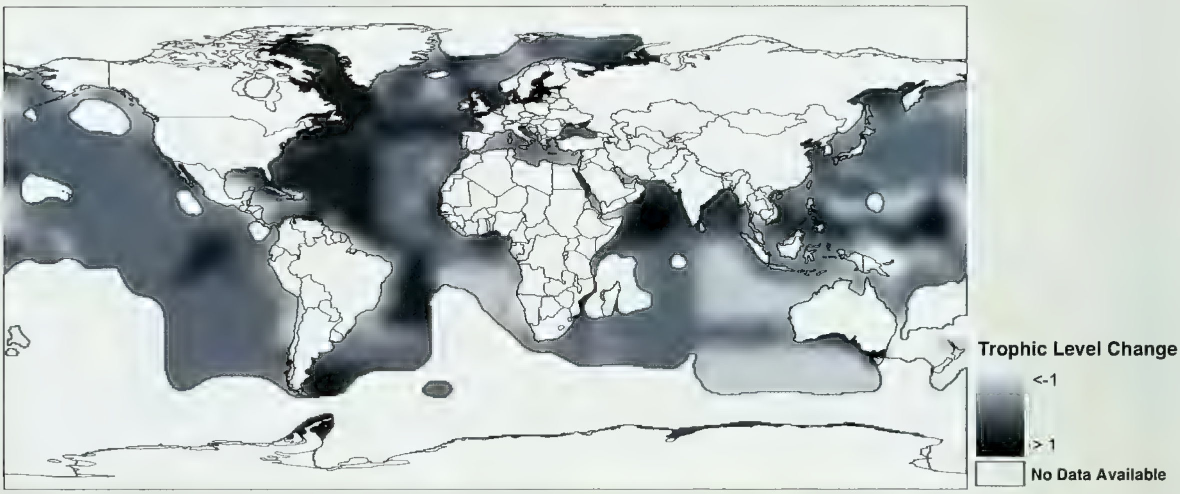
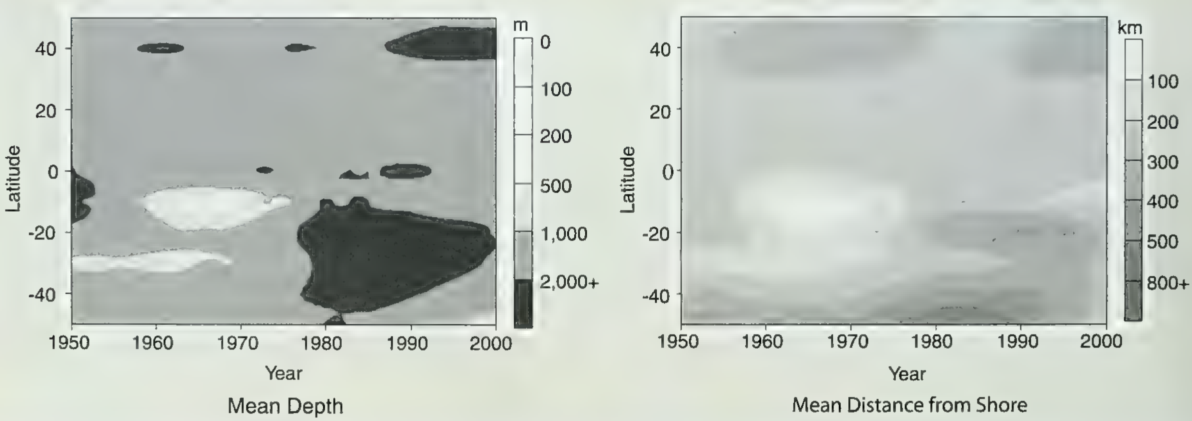


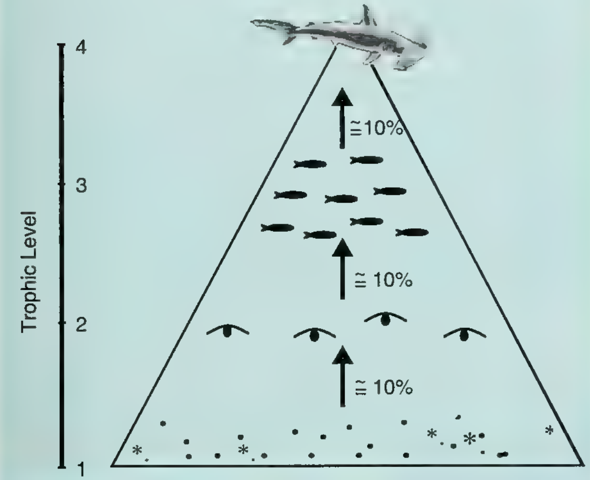
Figure 1.5 TREND IN MEAN DEPTH OF CATCH (LEFT) AND MEAN DISTANCE OF CATCH FROM SHORE (RIGHT) SINCE 1950

Both panels show that fisheries catches increasingly originate from deep, offshore areas, especially in the Southern Hemisphere [CT 18.2.1, Figure 18.5].



Box 1.1 TROPHIC LEVELS [CT 8, Box 8.3]

One way to understand the structure of ecosystems is to arrange them according to who eats what along a food chain. Each level along the chain is called a trophic level. Levels are numbered according to how far particular organisms are along the chain from the primary producers at level 1 to the top predators at the highest level. Within marine ecosystems, large predators such as sharks and Pollock (saithe) are at a high trophic level, cod and sardines are in the middle, and shrimp are at a low trophic level, with microscopic plants (mainly phytoplankton) at the bottom sustaining marine life.



the total ingredients). Fishmeal, especially high-quality fishmeal, is often derived from fish that are suitable for human consumption. Feeding fish to produce fish has a high protein conversion rate. It is particularly controversial where fishmeal is derived from already depleted capture fisheries, with negative impacts on the trophic structure. Freshwater fish feeds contain a minimal amount of fishmeal and are composed of predominantly low-cost plant proteins [CT 26.1.2.6].

Bioprospecting

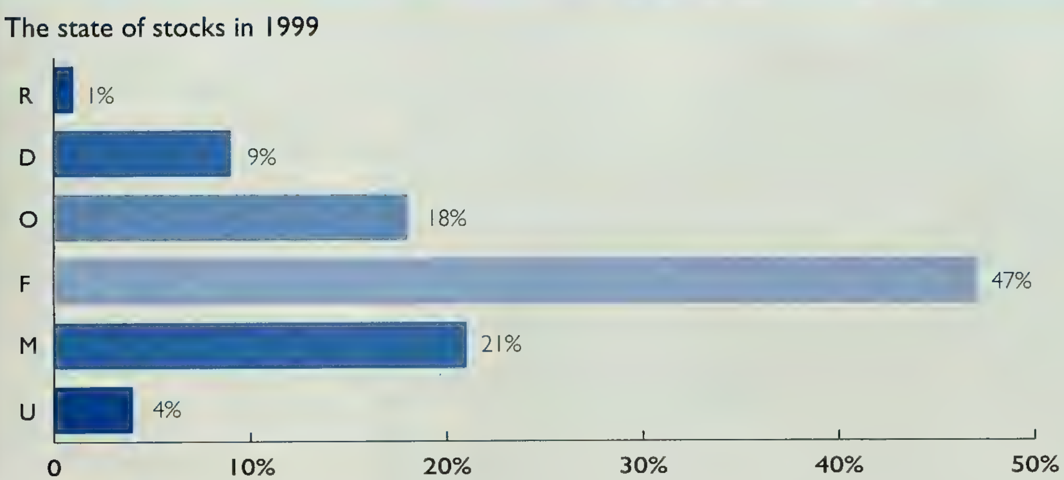
Bioprospecting (the exploration of biodiversity for new biological resources of social and economic value) has yielded numerous products derived from species in marine and coastal ecosystems (for example, antibiotics, antifreeze, fibre optics, and antifouling paints). Coral reefs are exceptional reservoirs of natural bioactive products, many of which exhibit structural features not found in terrestrial natural products [CT 19.3.2.1]. Mangrove forests are good reservoirs for medicinal plants.

The pharmaceutical industry has discovered several potentially useful substances, such as cytotoxicity (useful for anti-cancer drugs) among sponges, sea mosses, jellyfish and starfish [CT 10.2.1]. Cone shells of the molluscan family Conidae are highly prized for their highly variable toxins (conotoxins), applicable to many areas of medicine including pain control, cancer treatment, and microsurgery [CT 10.7.4].

Provision of Building Materials

Many marine and coastal ecosystems provide coastal communities with construction materials (such as lime for use in

Figure 1.6 THE STATE OF FISH STOCKS IN 1999 [CT 4.5.1.5, Figure 4.21]



R = recovering D = depleted O = overexploited
F = fully exploited M = moderately exploited U = underexploited

Source: FAO

WORLD FISHERY PRODUCTION AND UTILIZATION, 1996–2001 [CT 8, Table 8.4]
2001 data are projections from Fisheries Centre, University of British Columbia

	1996	1997	1998	1999	2000	2001
PRODUCTION (million tonnes)						
Inland	23.3	25.0	26.5	28.7	30.2	31.2
Capture	7.4	7.6	8.0	8.5	8.8	8.8
Aquaculture	15.9	17.5	18.5	20.2	21.4	22.4
Marine	96.9	97.5	91.3	98.0	100.2	97.6
Capture	86.0	86.4	79.2	84.7	86.0	82.5
Aquaculture	10.8	11.2	12.0	13.3	14.1	15.1
Total Production	120.2	122.5	117.8	126.7	130.4	128.8
Total capture	93.5	93.9	87.3	93.2	94.8	91.3
Total aquaculture	26.7	28.6	30.5	33.4	35.6	37.5
UTILIZATION						
Human consumption	88.0	90.8	92.7	94.5	96.7	99.4
Non-food uses	32.2	31.7	25.1	32.2	33.7	29.4
Population (billions)	**5.7**	**5.8**	**5.9**	**6.0**	**6.1**	**6.1**
Per capita fish consumption (kg)	15.3	15.6	15.7	15.8	16.0	16.2

mortar and cement) and other building materials from the mining of coral reefs [CT 19.2.1.4 and 19.5.1]. Mangroves provide coastal and island communities in several world regions with building materials for boat construction. The existence of alternative materials for boat building is not always apparent. Conservation projects play an important role in highlighting the alternatives and in providing training on how to use them [CT 19.6].

Regulating Services

Regulating services are the benefits people obtain from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification, among others.

Ecosystems such as mangroves, seagrass, rocky intertidal, nearshore mudflats, and deltas play a key role in shoreline stabilization, protection from floods and soil erosion, processing pollutants, stabilizing land in the face of changing sea level by trapping sediments, and buffering land from storms. Mangroves have a great capacity to absorb heavy metals and other toxic substances in effluents, while coral reefs buffer land from waves and storms and prevent beach erosion. Estuaries, marshes, and lagoons play a key role in maintaining hydrological balance and filtering water of pollutants [CT 19.2.1.1]. Dune systems and seagrass also play a notable role in trapping sediments (acting as sediment reserves) and stabilizing shorelines.

Marine ecosystems play significant roles in climate regulation [CT 18.1]. CO_2 is continuously exchanged between the atmosphere and ocean; it dissolves in surface waters and is then transported to the deep ocean (the 'solubility pump'). It takes roughly one year for CO_2 concentration in surface waters to equilibrate with the atmosphere. Subsequent mixing of the surface waters and deep waters is a much slower process allowing for the uptake of increased atmospheric CO_2, over decades to centuries. Marine plants (phytoplankton) fix CO_2 in the ocean (photosynthesis) and return it via respiration. It has been widely assumed that ocean ecosystems are at steady state at present, but there is now much evidence of large-scale trends and variations. Changes in marine ecosystems, such as increased phytoplankton growth rate due to the fertilizing effect of iron in dust and shifts in species composition, have the potential to alter the oceanic carbon sink. The net impact of biological changes in oceans on global CO_2 fluxes is unknown [CT 13.2.1]. A case study of the Paracas National Reserve, Peru (a Ramsar site, that is, designated as an internationally important wetland) showed the value of indirect use; its value—calculated through a model accounting for carbon sequestration by phytoplankton—was $181,124.00 per year [CT 19, Box 19.1].

Cultural and Amenity Services

Cultural services encompass such things as tourism and recreation; aesthetic and spiritual services; traditional knowledge; and educational and research services.

Tourism and Recreation

Among the most important cultural services provided by the coastal and marine ecosystems are tourism and recreation, but the capacity of these ecosystems to provide/deliver the services is being seriously degraded.

Global tourism has been deemed the world's most profitable industry, and coastal tourism is one of its fastest growing sectors. Despite multiple international crises (economic recession, SARS, terrorist attacks, and the war on terrorism),

international tourism has grown 4–5% in the past decade [23.2.5.2]. Much of this tourism centres on aesthetically pleasing landscapes and seascapes; intact healthy coastal ecosystems with good air and water quality; and opportunities to see diverse wildlife. Biodiversity plays a key role in the nature-based tourism industry of many islands and is the major tourism attraction for islands. (See Box 1.2.) For instance, coral reefs support high biodiversity that in turn supports a thriving and valuable dive tourism industry [CT 19.2.1.4] and recreation industry (such as recreational fishing) [CT 18.4].

Natural amenities are highly valued by people and contribute to human welfare, thus providing significant economic value. Stretches of beach, rocky cliffs, estuarine and coastal marine waterways, and coral reefs provide numerous recreational and scenic opportunities. Boating, fishing, swimming, walking, beachcombing, scuba diving, and sunbathing are among the numerous leisure activities that people enjoy worldwide and thus represent significant economic value [CT 19.3.2.2].

Rapid and uncontrolled tourism growth can be a major cause of ecosystem degradation and destruction, and can lead to the loss of cultural diversity [CT 23.2.5.2]. For example in several small island developing states, freshwater shortage is amplified by the lack of effective water delivery systems and waste treatment, coupled with increasing human populations and expanding tourism, both of which may result in the overabstraction of water, contamination through poor sanitation and leaching from solid waste, and the use of pesticides and fertilizers [CT 23.2.3.1].

Tourism development without proper planning and management standards and guidelines poses a threat to biodiversity. This is compounded by the fact that environmental impacts are often not clearly visible until their cumulative effects have destroyed or severely degraded the natural resources that attract tourists in the first place, and some destinations have only recognized the costs of environmental damage after significant and often irreversible damage has been done [CT 23.2.5.2].

Biopiracy has also been recorded in areas used for ecotourism, and the Maldives and Pacific Island states have been particularly vulnerable to such thefts [CT 23.2.5.1].

Cultural and Spiritual

Some species are of considerable cultural importance, for example the cultural significance of salmon in the aboriginal culture of the Northeast Pacific. The seas and coasts are also of great *spiritual importance* to many people around the world, such values are difficult to quantify. For example, the Bajau peoples of Indonesia and the aboriginal people of the Torres Strait (Australia) have a culture intimately connected to oceans, while many of the native peoples of North America have similar strong ties to coastal ecosystems [CT 19.3.2.2].

Traditional Knowledge

The term 'traditional ecological knowledge' (TEK) commonly refers to the knowledge that indigenous and other traditional peoples have about their environment, which is used to sustain themselves and to maintain their cultural identity [CT 23.2.5.1]. Our understanding of the tangible benefits derived from TEK, such as medicinal plants and local species of food, is relatively well developed [CT 17, Main Message #2] and covers a wide range of subjects, from agriculture, fishing, plants, and forests to general aspects of culture [CT 23.2.5.1]. (See Box 1.3.)

TEK is an integral part of the dynamics of some island ecosystems and the islanders who live there. Many stories and beliefs of islanders show the role of traditional villages and communities in improving the marine environment [CT 23.2.5.1].

The greatest use of TEK on islands relates to sustainable use and management within customary inshore fishing grounds, for example in Fiji, in the customary prohibition on the use of

resources (ra'ui) in Rarotonga in the Cook Islands, and in the village reserves in Samoa in the Pacific. Traditional ecological knowledge and customary sea tenure are also integrated into the conservation management of bumphead parrotfish (*Bolbometopon muricatum*) in Roviana Lagoon in the Solomon Islands [CT 23.2.5.1].

TEK has also been of direct benefit in the protection of reefs from adverse impacts from commercial and recreational fisheries, scuba diving, snorkelling, aquarium fish collection, and onshore development. For example, it has helped ensure sustainable development of the intertidal zone, with a focus on shellfish gathering and marine tenure in the atoll communities of western Kiribati, Micronesia, which are under pressure from population growth, urbanization, extractive technologies, and expanding market opportunities [CT 23.2.5.1].

Education and Research

Marine and coastal ecosystems are areas that have received attention through research. Rocky intertidal habitats have been the main focus of research that has provided the foundation for much of our knowledge of predator-prey interactions, keystone species, and other biological regulations [19.2.1.3].

Education on marine ecosystems is underfunded and underdeveloped. Further applied multidisciplinary research on ecosystem function, sustainable yields, and economic valuation of coastal ecosystems is also needed. Research focused on fundamental questions about ecosystem function, impacts, and efficacy of management measures will aid decision-makers in mitigating loss and degradation of these habitats. Fully protected areas help in this regard because they provide crucial control sites to test management interventions and allow for baseline monitoring. Better economic valuations (particularly quantitative estimates of marginal benefits) are also required to understand fully the importance of coastal ecosystems [CT 19.5.2].

Box 1.2 ECOTOURISM AND SMALL ISLAND STATES [CT 23.2.5.2]

Tourism is an important contributor to or dominates the economies of many small island states. The Caribbean is the most tourism-dependent region in the world and accounts for about 50% of the world's cruise tourism berths; the Maldives is the most tourism-dependent country. Tourism based on the natural environment is a fast-growing component of the tourism industry. In the last decade, nature (or eco-) tourism, which can be defined as travel to unspoiled places to enjoy nature, has emerged as the fastest growing segment of the industry, with an estimated growth rate of 10–30% annually. Of the various forms of nature tourism, coastal/marine tourism, including islands, is the largest component. Biodiversity plays a key role in the nature tourism development of many islands and is the major tourism attraction for islands such as Madagascar and Borneo. Ecotourism extends as far as the sub-Antarctic islands, where special voyages give tourists the experience of a variety of marine and pelagic fauna, using the islands as a base.

There is a great potential in many SIDS for the further development of ecotourism, which is often a small but rapidly growing share of their market economy. Ecotourism can provide employment and generate income while helping to protect and conserve natural resources and contributing to the implementation of national biodiversity action plans.

Tourism has great potential for biodiversity conservation and the promotion of the sustainable use of natural resources. In the Seychelles, for instance, tourism has been a major force and source of funding for biodiversity management and conservation, as well as ecosystem rehabilitation. In many cases, tourism is the only means by which a management infrastructure can be put in place on isolated islands to enable conservation activities. Indeed, well-informed tourists are increasingly the driving force behind the tourism industry's involvement in biodiversity management.

Supporting Services

Supporting services include provision of habitats, primary productivity, nutrient cycling, and soil formation.

Provision of Habitats and Nurseries

It is important to recognize that many habitats discussed throughout this report are both regionalized and widespread throughout the word. Habitats provide a range of services, for example mangrove forests. (See Figure 1.7.)

A large number of marine species use coastal areas, especially estuaries, mangroves, and seagrasses, as nurseries. *Estuaries* are particularly important as nursery areas for fisheries and other species, and they form one of the strongest linkages between coastal, marine, and freshwater ecosystems and the ecosystem services they provide [CT 19.2.1.1].

In some places, *mangroves* not only provide nursery areas for reef organisms but also link seagrass beds with associated coral reefs. Removal of mangrove can interrupt these linkages and cause biodiversity loss and lower productivity in reef and seagrass habitats. Mangroves also have a great capacity to absorb heavy metals and other toxic substances in effluents [CT 19.2.1.2].

Seagrass is important in providing nursery areas in the tropics, where it provides crucial habitat for coral reef fishes and invertebrates. Seagrass is an important source of food for many species of coastal and marine organisms in both tropical and temperate regions. Drift beds, composed of mats of seagrass floating at or near the surface, provide important food and shelter for young fishes, and the deposit of seagrass castings and macroalgae remnants on beaches is thought to be a key pathway for nutrient provisioning to many coastal invertebrates, shorebirds, and other organisms [CT 19.2.1.5].

Kelp forests and other macroalgae provide specialized nursery habitats for some species. For instance, the canopy or upper layers of kelp provides nursery habitat for young rockfish and other organisms. Kelp communities consist of several distinct canopy types supporting many herbivores (for example, sea urchins) [CT 19.2.1.6]. The interaction between sea urchins and sea otters maintains the kelp forests' structure.

Box 1.3 TRADITIONAL KNOWLEDGE IMPORTANT TO ENVIRONMENTAL MANAGEMENT OF MARINE AND COASTAL ECOSYSTEMS [modified from CT 23.2.5.1]

Fishing

- Fishing methods and materials
- Knowledge of fish species and their behaviour, migration, and reproduction
- Best fishing locations, times, and techniques for each species
- Controls on fishing: limited access to fishing areas, taboo areas or seasons, catch restrictions
- Changes in fishing resources, effects of overfishing, 'how things used to be'

General

- Traditional names for, and classifications of, species and communities
- Calendars related to the weather, to celestial bodies (solar and lunar cycles, appearance or movement of stars), or to the migration of birds and fish
- Weather patterns and prediction, cycles of rain and drought, changes in climate
- Natural catastrophes, cyclones, tsunamis, floods; signs and warnings; effects and areas affected
- Changes in the environment, former locations and populations of villages
- Environmental knowledge: who possessed it, how it was used and transmitted

Estuaries also provide a range of habitats to sustain diverse flora and fauna. For example, there are many more estuarine-dependent species than estuarine-resident species [19.2.1.1]. *Mudflats* are also critical habitat for migrating shorebirds and many marine organisms, including commercially important species like the horseshoe crab (*Limulus polyphemus*) and a variety of clam species. Soft bottom coastal habitats are highly productive, and can have a species diversity that may rival that of tropical forests.

Dunes support high species diversity in certain taxonomic groups, including endangered bird, plant, and invertebrate species [CT 19.2.1.3].

All of these ecosystems—beaches, sandy shores, dune systems, saltmarshes, estuaries, and mudflats—provide feeding and nesting habitats to numerous species of birds, fish, molluscs, crustaceans, and other ecologically and commercially important organisms [CT 19.2.1.1].

Primary Productivity

Marine and coastal ecosystems play an important role in photosynthesis and productivity of the systems. Marine plants (phytoplankton) fix CO_2 in the ocean (photosynthesis) and return it via respiration. It had been widely assumed that ocean ecosystems are currently at a steady state; however, there is now much evidence of large-scale trends and variations. Changes in marine ecosystems, such as increased phytoplankton growth rate due to the fertilizing effect of iron in dust and shifts in species composition, have the potential to alter the oceanic carbon sink and primary productivity; activities that trigger such changes should be considered with extreme caution [CT 13.2.1].

Nutrient Cycling and Fertility

One of the most important processes occurring within estuarine environment is the mixing of nutrients from upstream as well as from tidal sources, making estuaries one of the most

Figure 1.7 GLOBAL DISTRIBUTION OF MANGROVE FORESTS

Map A shows mangrove distribution in Latin America, Map B shows mangrove distribution in Africa, and Map C displays mangrove distribution in the Asia-Pacific region [CT 19, Figure 19.5].

fertile coastal environments. Mangroves and saltmarshes play a key role together in cycling nutrients. For example, saltmarshes in the Red Sea region contribute nitrogen to adjacent mangroves. Beaches and sandy shores are important in the delivery of land-based nutrients to the nearshore coastal ecosystem.

Habitat and Biodiversity Loss

Overfishing, destructive fishing practices, habitat loss, pollution, and other human impacts have resulted in the destruction and modification of coastal habitats around the world (Table 1.2), reducing their ability to provide these services and threatening biodiversity. (See Box 1.4 for examples of threatened species.) Coastal habitats are tightly interlinked, so that the loss of one habitat can have flow-on effects that degrade and reduce the services provided by linked habitats. (See Box 1.5 for general information about condition and trends of marine and coastal ecosystems.)

Estuaries

Worldwide, over 1,200 major estuaries have been identified and mapped, with a total area of approximately 500,000 km^2. These 1,200 estuaries, including lagoons and fiords, account for approximately 80% of the world's freshwater discharge. Sixty-two percent of the world's major estuaries occur within 25 km of urban centres having 100,000 or more people [CT 19.2.1.1]. There has been a substantial loss of estuarine habitat and associated wetlands globally. In California (United States), for example, less than 10% of natural coastal wetlands remain, while in the United States more generally, over half of original estuarine and wetland areas have been substantially altered. In Australia, 50% of estuaries remain undamaged, although these estuaries are away from current population centres.

Mangroves

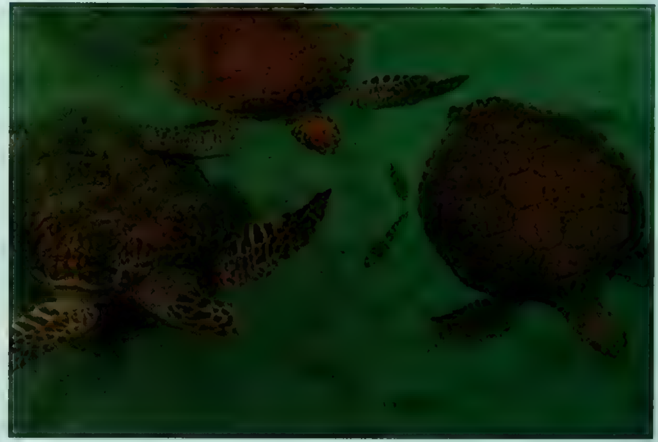
Global mangrove forest cover currently is estimated between 16 and 18 million hectares. Much of the coastal population of the tropics and subtropics resides near mangroves; 64% of all the world's mangroves are currently within 25 km of major urban centres having 100,000 people or more [CT 19.2.1.2]. Many of the world's mangrove areas have become degraded due to population pressures, widespread habitat conversion, and pollution. For countries with available data (representing 54% of total current mangrove area) an estimated 35% of mangrove forests have disappeared in the last two decades at the rate of 2.1% per year, or 2,834 km^2 per year, and mangroves have dramatically declined in nearly every country for which data have been compiled. In some countries, more than 80% of original mangrove cover has been lost due to deforestation.

The leading human activities that contribute to mangrove loss are: 52% aquaculture (38% shrimp plus 14% fish), 26% forest use, and 11% freshwater diversion. Restoration has been successfully attempted in some places, but has not kept pace with wholesale destruction in most areas [CT 19.2.1.2].

Coral Reefs

Coral reefs are highly degraded throughout the world, and it is likely that there are no pristine reefs remaining. Most tropical reefs occur in developing countries, and this is where the most intensive degradation is occurring. Of all the world's

Box 1.4 EXAMPLES OF COASTAL AND MARINE SPECIES UNDER THREAT



All seven species of sea turtles are listed under the Convention on International Trade in Endangered Species (CITES). According to the IUCN Red List, three are critically endangered, three are endangered, and the status of the Australian flatback turtle (*Chelonia depressa*) is unknown [CT 19.2.2.1 and 19.2.2.2].

The Atlantic grey whale and Caribbean monk seal have been driven to extinction.

Many dolphins are threatened by bycatch [CT 19.2.2.2.].

Globally, 91% of albatross species, 59% of penguins, 43% of shearwaters, and 40% of frigate birds are threatened [CT 19.2.2.3].

Shorebirds are declining worldwide: of populations with a known trend, 48% are declining and only 16% are increasing. Overall 45 (34%) of African-Eurasian migratory shorebird populations are regarded as 'of conservation concern' due to their decreasing and/or small populations [CT 19.2.2.3].

Of the shark, ray, and chimaera species assessed by IUCN, 18% are listed as threatened, 19% near threatened, 37.5% data deficient, and 26% least concern [CT 4.4.2.2]. On the coast of southern California, the California mussel *Mytelus californianus* has become very rare, the ochre sea star is now almost never seen, the once abundant black abalone can no longer be found, and dozens of formally abundant nudibranch species are now rare.

Some species of crocodiles are under threat of extinction, although none of the 23 known species has actually gone extinct.

Box 1.5 GENERAL CONDITIONS AND TRENDS OF COASTAL AND MARINE BIODIVERSITY

An increasing number of studies are highlighting the inherent vulnerability of marine species to overexploitation. Particularly susceptible species tend to be both valuable and relatively easy to catch as well as having relatively slow population production rates. Thus species such as large groupers, croakers, some sharks, and skates are particularly vulnerable.

Assessment of the condition and trends of marine biodiversity is limited by a lack of knowledge and previous assumptions of marine fish and invertebrate abundance. Information on habitat types, as well as species diversity and distributions and the factors that influence them, is only just emerging, as are methods for measuring diversity and its patterns. Our understanding of the condition and trends of marine biodiversity will improve significantly if new methods are applied and monitoring activities are put into place [CT 18.3.6.1].

There is, however, increasing evidence of threats to, and the loss of, marine and coastal biodiversity. The World Wide Fund for Nature's (WWF) Living Planet Index (LPI), currently one of the best estimate of global population trends, estimates a decline of 30% in the marine species population index between 1970 and 2000 [CT 4.4.1]. The status of coastal and sea birds is deteriorating in all parts of the world and across all major habitat types. The IUCN Red List demonstrates that birds dependent on marine and coastal ecosystems have declined faster than other birds (see Figure 1.8).

known tropical reef systems, 58% occur within 25 km of major urban centres having populations of 100,000 or more. In 1999, it was estimated that approximately 27% of the world's known reefs had been badly degraded or destroyed in the last few decades. The coral reefs of the Caribbean Sea and portions of Southeast Asia have suffered the greatest rates of degradation and are expected to continue to be the most threatened [CT 19.2.1.4].

Our knowledge of cold-water coral diversity is limited, with many new reefs still being discovered. The biggest threat to deep-sea coral reefs comes from bottom trawling activities. WWF suggests that 30–50% of the cold water corals along the Norwegian coast have already been lost due to bottom trawling, marine pollution, and oil and gas exploration [CT 18.3.6.2].

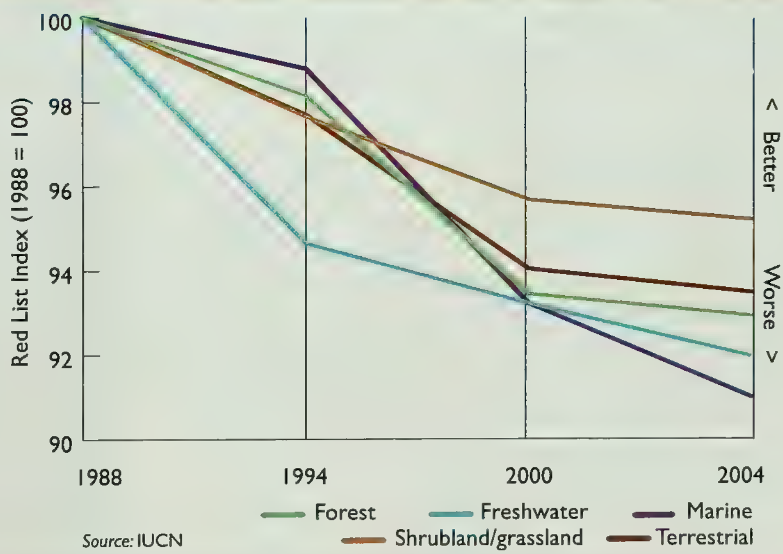
Intertidal Habitats and Deltas

Food and bait collection (including molluscs and seaweeds) and human trampling have substantially depleted many of the organisms in these habitats. In the United States, the rocky intertidal zone has undergone major transformation in the last few decades. Similar trends have been observed elsewhere in the world. Along the Yellow Sea coast, China has lost around 37% of habitat in intertidal areas since 1950, and South Korea has lost an estimated 43% since 1918 [CT 19.2.1.3].

Deltas are high population and human land use areas and have been identified, along with estuaries and small islands, by the Intergovernmental Panel on Climate Change as the coastal ecosystems most vulnerable to climate change and sea-level rise.

Figure 1.8 RED LIST INDICES FOR BIRDS IN FRESHWATER, MARINE, AND TERRESTRIAL ECOSYSTEMS, AND FOR BIRDS IN FOREST AND SHRUBLAND/GRASSLAND HABITATS [CT 20, Figure 20.67]

It has been widely assumed that marine fish and invertebrates are less susceptible to extinction than most other marine species such as marine mammals or than terrestrial and freshwater organisms. However, there is an emerging consensus that marine fish are no more resilient to extirpation or extinction than other wildlife species [CT 18.3.6.1]. The reduced biomass and fragmented habitats resulting from overexploitation of marine resources is likely to lead to numerous extinctions, especially among large, long-lived, late-maturing species, which also tend to be valuable and easy to catch. One well-documented example of localized extinction is that of the historic fishing grounds ranging from New England to Newfoundland and Labrador that once supported immense fisheries of cod [CT 18.3.6.3]. There is also increasing evidence that many marine populations do not recover from severe depletion, even when fishing has stopped [CT 4.3.5].



Source: IUCN

Beaches and Dunes

Disruptions to the sand balance through activities such as sand mining, nearshore aggregate extraction, and the construction of artificial coastal barriers in many locations are causing the total disappearance of beaches. Encroachment in dune areas often results in shoreline destabilization, resulting in expensive public works projects such as the building of breakwaters or seawalls and sand re-nourishment [CT 19.2.1.3].

Seagrass Beds

Major losses of seagrass habitat have been reported from the Mediterranean, Florida Bay, and Australia. Present losses are expected to accelerate, especially in Southeast Asia and the Caribbean [CT 19.2.1.5].

Increased nutrient input to shallow-water coastal areas with limited flushing (prime areas for seagrass growth) encourages the growth of fouling organisms causing algal and epifaunal encrustation of seagrass blades, limiting the ability of the seagrass to photosynthesize and in extreme cases smothering the meadows altogether [CT 19.2.1.5].

Kelp Forests

The biological communities of many kelp forests have been so destabilized by fishing that they retain only a fraction of their former diversity. It is likely that no kelp systems exist in their natural condition. Fishing impacts can reduce diverse kelp forests to greatly simplified sea urchin-dominated barren grounds [CT 19.2.1.6].

Saltmarshes or Ponds

Saltmarshes and coastal peat swamps have undergone massive change and destruction, both in estuarine systems and along the coast. Saltmarsh subsidence has occurred in part due to reduced sediment delivery from watersheds. Countries monitoring changes in peat swamps in Southeast Asia find that such swamps have declined from 46–100% [CT 19.2.1.1].

Semi-enclosed Seas

Semi-enclosed seas are becoming highly degraded. Freshwater inflows to semi-enclosed seas have been severely curtailed in most areas, robbing them of recharging waters and nutrients. A particularly acute case of this degradation has occurred in the Gulf of California, which now receives only a trickle of water through the now dry, but once very fertile, delta of the Colorado River. Poor water quality results from land-based sources of pollution such as agricultural and industrial waste. Limited flushing and long recharge times in semi-enclosed seas means that pollutants are not as quickly diluted as in the open sea, and eutrophication and toxics loading often results [CT 19.2.1.8].

Other Benthic Communities

Hard bottom and soft sediment seafloor habitats are severely impacted by fishing methods such as bottom trawling and dredging. This type of human disturbance is one of the most significant threats to marine biodiversity. Soft bottoms cover about 70% of the earth's seafloor and are characterized by extremely high species diversity. There is now strong evidence of fishing effects on seafloor communities that have important ramifications for ecosystem function and resilience. Fishing has already destroyed many hard-bottom communities [CT 19.2.1.7].

Seamounts interrupting the ocean floor's soft sediments are crucial to many pelagic fish species for breeding, spawning, and as safe havens for juvenile fishes seeking refuge from open ocean predators. These highly structured and diverse communities are also extremely vulnerable to fishing impacts [CT 19.2.1.7].

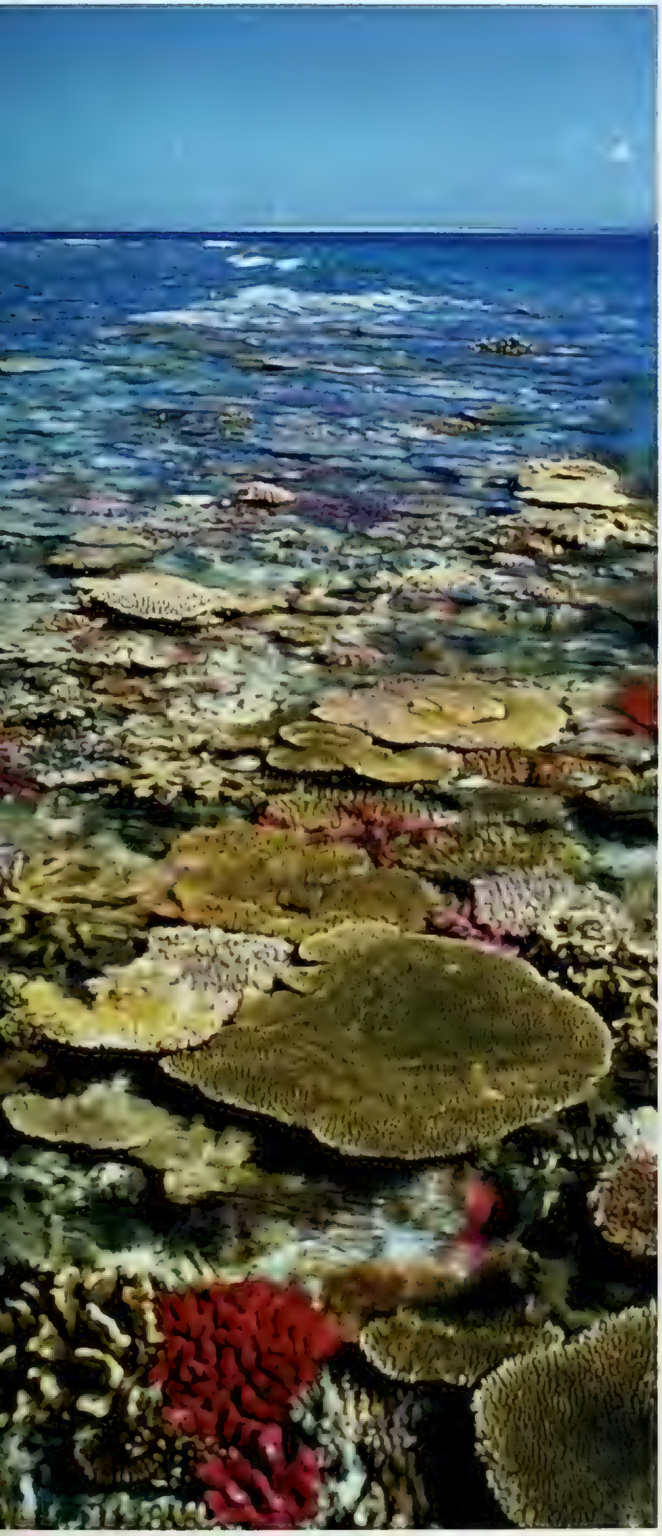
Gaps in Knowledge of Marine and Coastal Ecosystems

Gaps in Knowledge and Data

Long-term and large-scale ecological processes are generally poorly understood, and nowhere is this more true than in marine ecosystems [S 3.4.6]. For example:

- There is a lack of understanding of the oceanic nitrogen cycle, including biological N_2 fixation and N_2O production. This makes predicting the impacts of anthropogenic N inputs very difficult [S 3.4.6].
- The El Niño/Southern Oscillation, deriving from interactions between the ocean and the atmosphere in the Pacific, strongly influences the oceanic productivity in the eastern Pacific. It alternates on a period of between two to seven years. Understanding of this phenomenon has substantially improved over recent years, but it remains difficult to make predictions about its occurrence and impacts [S 3.4.4].

Basic data on the past and current extent and status of many marine and coastal ecosystems are not available or are of questionable quality. This makes accurate calculations of change and trends difficult. For example, in relation to the adequate delineation of coastal inland water, in particular wetlands, the following has been noted: 'The extent and distribution of inland waters is unevenly or even poorly known at the global and regional scales, due to differences in definitions as well as difficulties in delineating and mapping habitats with variable boundaries due to fluctuations in water levels'. In many cases comprehensive documentation at the regional or national levels does not exist. Larger wetlands, lakes, and inland seas have been mapped along with the major rivers, but for many parts of the world, the valuable and smaller wetlands are not well mapped or delineated. Mapped data contain many inaccuracies and gaps as well as differences due to scale and resolution. An example is northern Australia, where estimates of the area of inland water ecosystems from 10 data sources varied from 0–98,700 km^2 [CT 20.3.1].



Assessment of the extent of and change in inland water habitats at the continental level is compromised by the inconsistency and unreliability of the data. This is especially so when referring to smaller systems [CT 20.1].

Marine fish stocks are highly variable. Inadequate understanding of this variability greatly compounds the difficulties of fisheries management [CT 18.8.1]. It has not so far been possible to predict the critical thresholds beyond which a fish stock will collapse, and the major stock collapses that have happened in recent decades have been a surprise, even to those involved in monitoring and managing these stocks [CT 18.7.2]. With the unpredictability of these thresholds, precautionary approaches such as marine protected areas and reductions in fishing effort (and therefore fishing mortality) are likely to safeguard against such thresholds being reached [CT 18.8.2].

In general, our knowledge of biodiversity is uneven, with particular gaps in knowledge regarding the status of marine biota, along with freshwater biota, tropical ecosystems, plants, invertebrates, micro-organisms and subterranean biota. There are strong biases towards the species level, large animals, temperate ecosystems, and components of biodiversity used by people [CT 4, Main Message #3]. There is also limited knowledge of the subdivision of species into populations with distinct characteristics that are of evolutionary importance and of potential human use [CT 18.2.6.4]. Recent initiatives such as Census of Marine Life are increasing the rate at which new knowledge on marine life is becoming available [CT 18.2.6.1].

Gaps in Methodology to Assess Ecosystem Services

Assessment of fisheries has been dominated by single-species approaches, such as the widely applied maximum sustained yield (MSY) concept. These approaches look at target fish populations in isolation from the ecosystem. The MSY approach has been criticized for failing to recognize the role of trophic interactions and risking sharp population declines [S 3.5.2, 4.8]. Single-species approaches will continue to have a role in evaluating the dynamics of exploited stocks, but they need to be complemented by multi-species models [S 4.8].

Existing biodiversity indicators do not adequately reflect many important aspects of biodiversity, especially those that are significant for the delivery of ecosystem services [CT 4.5.1], and there is no agreement (at the time of writing) on a complete set of indicators to be used for the 2010 target, whose aim is 'to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional, and national level as a contribution to poverty alleviation and to the benefit of all life on earth'. There are no comprehensive global-scale measures to assess success in meeting the target. Available evidence, however, indicates that it is unlikely to be met: trends are still downwards for most species and populations, and the rate of decline is generally not slowing. This is also true for aggregate indices such as the Living Planet Index and the Red List Index [CT 4.5.3].

2 *What are the drivers of change in marine and coastal ecosystems?*

- Anthropogenic causes are the major drivers of change, degradation, or loss of marine and coastal ecosystems and services.
- The direct drivers of change in marine and coastal ecosystems are:
  - land use change;
  - development of aquaculture;
  - overfishing and destructive fishing methods;
  - invasive species;
  - pollution and nutrient loading (eutrophication); and
  - climate change.
- The major indirect drivers of change in marine and coastal ecosystems are:
  - shifting food preferences and markets;
  - subsidies;
  - illegal fishing;
  - population growth;
  - technology change; and
  - globalization.
- Terrestrial drivers also impact upon marine and coastal ecosystems.

Drivers of Change in Marine and Coastal Ecosystems

An array of anthropogenic and natural impacts has degraded, altered, or eliminated coastal and marine ecosystems. Drivers may either directly or indirectly impact upon ecosystems. The strongest drivers of change in marine and coastal ecosystem are land use change and habitat loss, fisheries, invasive species, pollution, nutrient loading (eutrophication), and climate change. Although terrestrial drivers also cause change to the marine and coastal ecosystems and services, they are not the primary focus of this discussion. Climate change and the introduction of invasive alien species are highlighted as the two direct drivers of change in marine and coastal ecosystems that are most difficult to reverse [CT 4.3.1]. Table 2.1 lists the important direct and indirect drivers identified in the MA overall, while Table 2.2 presents a typology of drivers of change in coastal systems and ecosystem services.

Direct Drivers of Change in Marine and Coastal Ecosystems

Land Use Change and Habitat Loss

Land use change and habitat loss and destruction have degraded or altered marine and coastal ecosystems in many areas and have a direct negative impact on biodiversity [CT 4.3]. Natural land cover has changed drastically under the pressure of growing human populations and consequent exploitation of the land mass and its offshore regions. On some islands, the impact has exceeded the critical point (that is, impacting human well-being), particularly along the coastal fringe [CT 23, Main Messages].

Excessive amounts of sedimentation due to land disturbance have been a global problem and coastal-marine habitats have been severely degraded. Sedimentation has also caused or accelerated infilling of many wetland habitats and lakes. It is possible that the retention of inland water systems would have ameliorated the impact of sedimentation on coastal ecosystems [CT 20.2.2].

In estuarine habitats, poor management and the destruction of large areas of an estuary's watershed often lead to degradation of estuaries. Agricultural and grazing practices that destroy natural riparian habitats have resulted in floods, and changes to freshwater flows through river impoundment and diversion have altered sediment delivery. Recent estimates suggest worldwide sediment delivery (and thus delivery of important nutrients) to estuaries has been reduced to 30% of original levels due to diversion and damming. Further, urbanization of watersheds interrupts natural flows of both freshwater and nutrients and increases pollution [CT 19.2.1.1].

Table 2.1 IMPORTANT DRIVERS IN THE MA

DIRECT DRIVERS	INDIRECT DRIVERS
Changes in climate	Demographic
Plant nutrient use	Economic
Land use management and change	Sociopolitical
Diseases	Scientific and technological
Invasive species	Cultural and religious
Pollution	

Table 2.2 DRIVERS OF CHANGE IN COASTAL ECOSYSTEMS [CT 19, Table 19.5]

DIRECT DRIVERS	INDIRECT DRIVERS
[illegible]	
Coastal development (ports, urbanization, tourism-related development, industrial sites)	Population growth; poor siting due to undervaluation; poorly developed industrial policy; tourism demand; environment refugees and internal migration
Destructive fisheries (dynamite, cyanide, bottom trawling)	Shift to market economies; demand for aquaria fish and live food fish; increasing competition in light of diminishing resources
Coastal deforestation (especially mangrove deforestation)	Lack of alternative materials; increased competition; poor lack of implementation of existing ones
Mining (coral, sand, minerals, dredging)	Lack of alternative materials; global commons perceptions
Civil engineering works	Transport and energy demands; poor public policy; lack of knowledge about impacts and their costs
Environmental change brought about by war and conflict	Increased competition for scarce resources; political instability; inequality in wealth distribution
Aquaculture-related habitat conversion	International demand for luxury items (including new markets); regional demand for food; demand for fishmeal in aquaculture and agriculture; decline in wild stocks or decreased access to fisheries (or inability to compete with larger-scale fisheries)
[illegible]	
Eutrophication from land-based sources (agricultural waste, sewage, fertilizers)	Urbanization; lack of sewage treatment or use of combined storm and sewer systems (CSS); unregulated agricultural development, loss of wetlands and other natural controls
Pollution: toxics and pathogens from land-based sources	Lack of awareness; increasing pesticide and fertilizer use (especially as soil quality diminishes); unregulated industry
Pollution: dumping and dredge spoils	Lack of alternative disposal methods; increased enforcement and stiffer penalties for land disposal; belief in unlimited assimilative capacities, waste as a commodity
Pollution: shipping-related	Substandard shipping regulations; no investment in safety; policies promoting flags of convenience; increases in ship-based trade
Salinization of estuaries due to decreased freshwater inflow	Demand for electricity and water; territorial disputes
Alien species invasions	Lack of regulations on ballast discharge; increased aquaculture-related escapes; lack of international agreements on deliberate introductions
Climate change and sea-level rise	Insufficient controls on emission; poorly planned development (vulnerable development); stressed ecosystems less able to cope
Overexploitation	
Directed take of low-value species at high volumes exceeding sustainable levels	Population growth; demand for subsistence and market (food and medicinal) industrialization of fisheries; improved fish-finding technology; poor regional agreements, lack of enforcement, breakdown of traditional regulation systems, subsidies
Directed take for luxury markets (high value, low volume) exceeding sustainable levels	Demand for specialty foods and medicines, aquarium fish, and curios; lack of awareness or concern about impacts; technological advances; commodification
Incidental take or bycatch	Subsidies; bycatch has no cost
Directed take at commercial scales; decreasing availability of resources for subsistence and artisanal use	Marginalization of local peoples; breakdown of traditional social institutions

Mangroves have been converted to allow for coastal zone development, aquaculture, and agriculture, including grazing and stall feeding of cattle and camels (which in Pakistan, for instance, is the second most serious threat to mangrove ecosystems). Mangrove forests are also affected by removal of trees for fuelwood and construction material, removal of invertebrates for use as bait, changes to hydrology in both catchment basins or nearshore coastal areas, and excessive pollution [CT 19.2.1.2].

Mudflats and saltmarshes are commonly destroyed during port and other infrastructure development or maintenance dredging, and coastal muds in many areas are highly contaminated by heavy metals, polychlorinated biphenyls (PCBs), and other persistent organic pollutants (POPs), leading to mortality and morbidity in marine species and human health impacts. Beaches and sandy shores have undergone massive alteration due to coastal development, pollution, erosion, storms, alteration to freshwater hydrology, sand mining, groundwater use, and harvesting of organisms [CT 19.2.1.3].

Coral reefs are at high risk from many kinds of human activity, including destructive fishing (for example, use of cyanide to stun and capture fish and explosives); collecting for the marine ornamental trade; diving; snorkelling; walking on reefs during low tide; tourism; collecting for use in construction and lime production; overfishing for both local consumption and export; inadequate sanitation and poor control of run-off leading to eutrophication; dumping of debris and toxic waste; land use practices leading to siltation; oil spills; and degradation of linked habitats such as seagrass, mangrove, and other coastal ecosystems [CT 19.2.1.4]. Similar processes affect seagrasses, but habitat conversion for algae farming is a major cause of damage to seagrasses globally [CT 19.2.1.5].

Development of Aquaculture

Aquaculture often has serious environmental impacts, issues concerning sustainability, and trade-offs between land uses. As discussed above, aquaculture is not considered to be sustainable if wild fisheries capture is used for feed [CT 8.2.1]. The rapid increase in coastal aquaculture has led to the loss of many mangrove ecosystems, typically through conversion to shrimp or prawn farms. This destruction of mangrove is particularly wasteful and costly in the long term, since shrimp ponds created out of mangrove forest lose their productivity over time and tend to become fallow within 2–10 years. Historically, abandoned shrimp ponds were rarely restored, but new policy directives and a shift in the aquaculture industry are helping to make aquaculture less destructive and more prone to supporting restoration and/or regrowth in some parts of the world [CT 19.2.1.2].

Aquaculture operations have impacts on water quality and salinization of adjacent agricultural lands, although effluents from freshwater aquaculture are less polluting than those from brackish water and marine aquaculture [CT 26.2.2.3]. Discharge from aquaculture facilities can be loaded with pollutants which degrade the surrounding environment, including excess nutrients from uneaten fish feed and fish waste, antibiotic drugs, and other chemicals, including disinfectants such as chlorine and formaline, antifoulants such as tributyltin, and inorganic fertilizers such as ammonium phosphate and urea. The use of antibiotics and other human-made drugs can also have serious health effects on humans, the ecosystem, and other species [CT 7.4.5.2].

Infectious disease is currently a serious problem in aquaculture, not only to the fish being farmed but to wild populations as well. When infected farmed fish escape from aquaculture facilities, they can transmit these diseases and parasites to wild stocks. Infectious salmon anemia (ISA), a deadly disease affecting Atlantic salmon, poses a serious threat to the salmon farming industry. Norwegian field studies observed that wild salmon often become heavily infected with sea lice (parasites that eat salmon flesh) while migrating through coastal waters, with the highest infection levels occurring in salmon-farming areas [CT 4.3.4].

The expansion of the shrimp industry in Ecuador has brought about economic growth and employment, but it has also changed the allocation and flow of labour, reduced flexibility and diversity of household economies, and brought about large-scale loss of mangroves.

Overfishing and Destructive Fishing Methods

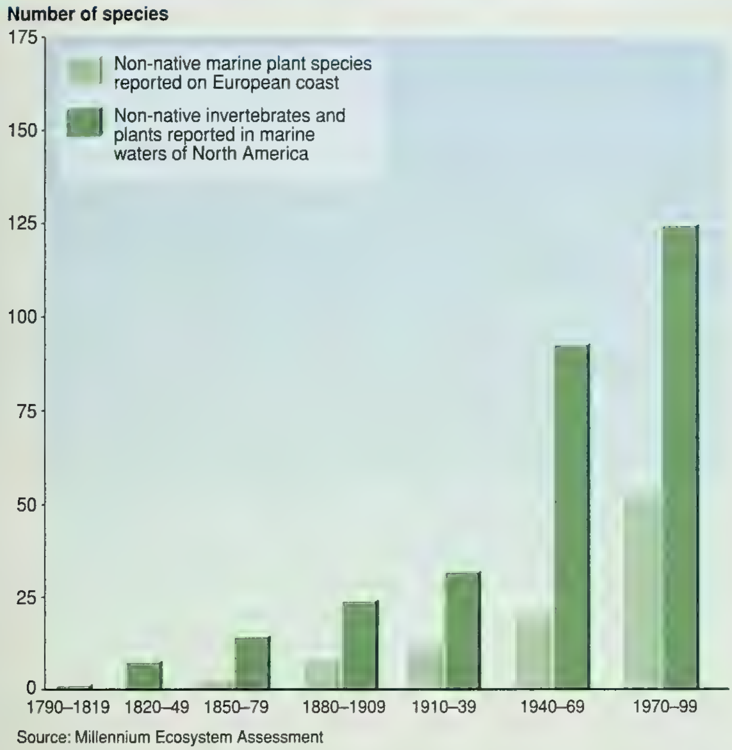
Overfishing and destructive fishing methods such as trawling (for example, use of heavy gear on sensitive substrates), dredging, and the use of explosives and poisons such as cyanide impact on the marine ecosystems in two ways: by changing community structure and altering trophic and other interactions between ecosystem components and by physically modifying habitats, notably when trawlers erode biogenic bottom structures. Once altered, ecological states may be impossible to restore to former conditions [CT 18.2.6.2]. A large number of marine species use coastal areas, especially estuaries, mangroves, and seagrasses, as nurseries. Thus modifying coastal habitat and coastal pollution, as well as inshore fishing, can adversely impact offshore fisheries by reducing the supply of recruits to the offshore adult stocks [CT 18.3.2]. Area closures and the halt of destructive fishing have resulted in improvements to the fisheries, especially in coral reefs. Overall, however, the trend is that overfishing and habitat destruction continue throughout the world [CT 18.4.1.3].

Fisheries bycatch is a major threat to biodiversity. Turtles [CT 19.2.2.1], seabirds [CT 19.2.2.3], and sharks [CT 4.4.1.5], for example, all suffer declines due to bycatch from pelagic longline fisheries. It is well documented that the main driver for adult mortality among albatrosses, the seabirds showing the most dramatic current population declines, is caused by pelagic longline fisheries in the southern oceans.

Invasive Species

Invasive species have been recognized as a major driver of ecosystem change and are expected to grow in importance,

Figure 2.1 GROWTH IN NUMBER OF MARINE SPECIES INTRODUCTIONS



Number of new records of established non-native invertebrate and algae species reported in marine waters of North America, shown by date of first record, and number of new records of non-native marine plant species reported on European coasts, by date of first record [General SR, Figure 1.7].

contributing to species extinction and the deterioration of ecosystem services. This is due to the expected increase of unintended introductions of non-native organisms as a side effect of growing global trade. The exchange of non-native species between the Baltic Sea in Europe and the North American Great Lakes region has been well studied. A high proportion of the 100 or so non-native species in the Baltic region derive from the Great Lakes; and in the latter region, 75% of the recent arrivals of the 150 non-native species come from the Baltic Sea. Some of those species have even been introduced to the Baltic Sea from other regions. (See Figure 2.1.) A major source of marine introductions of non-native species is the unintentional release through the ballast water from ships [S 10.5].

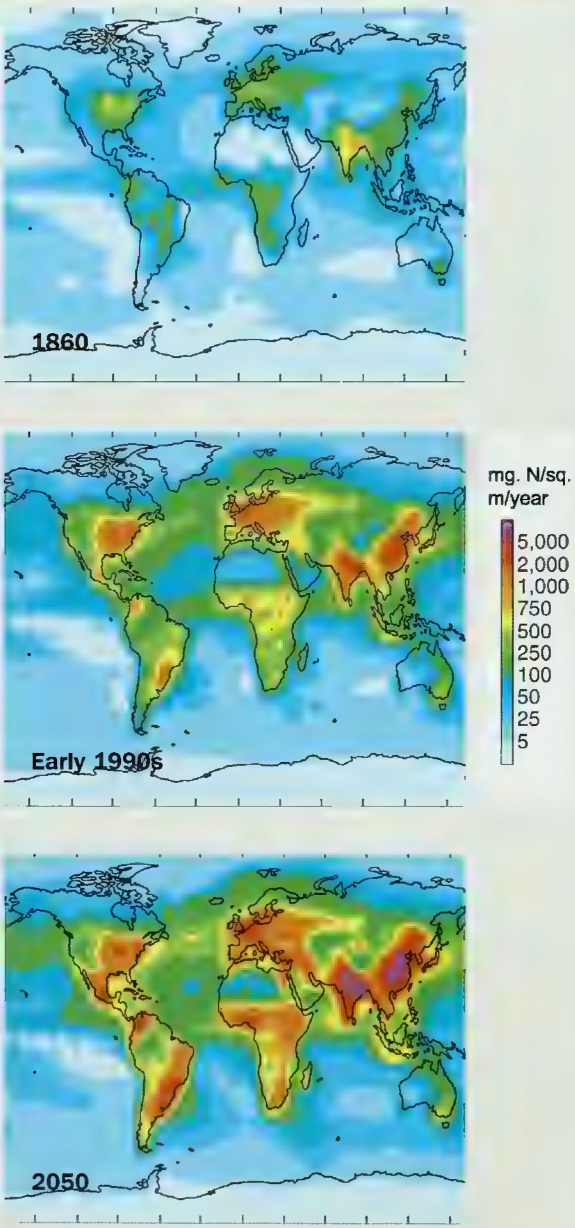
The introduction of alien species—in some cases intentional (for example, species released for hunting or introduced as a biological control) but more commonly unintentional (for example, introduced with traded goods such as lumber or in the ballast water of ships)—has the effect of homogenization and in many cases extirpation of native endemic species and habitat alterations [CT 4.3.2]. Introductions of exotic mammals (for example, rats, cats, rabbits, pigs) have had substantial impacts on many island ecosystems, particularly on seabirds nesting safely on the ground or in burrows. These mammals generally reduced, and in some cases drove to extinction, populations of marine birds, waterfowl, and other ground-nesting birds, through either habitat alteration or direct predation [CT 25.3.6].

There is also now strong evidence in several marine ecosystems that species richness increases invasion resistance. Diverse ecosystems more completely utilize resources such as available space. In experimentally assembled benthic (sea floor) communities, decreasing the richness of native taxa was correlated with increased survival and percent cover of invading species. Open space was the limiting resource for invaders, and a higher species richness buffered communities against invasion through increasing temporal stability (for example, reducing fluctuations of open space) [CT 11.4.1].

Pollution and Nutrient Loading (Eutrophication)

Eutrophication, or nutrient pollution, has become a driver of change for coastal and marine ecosystems. The nutrients (nitrogen and phosphorus) come from three main sources: agricultural run-off, sewage, and burning of fossil fuels. Through the stimulated growth of algae, eutrophication leads to a depletion of oxygen (creating 'dead zones'), which reduces the

Figure 2.2 ESTIMATED TOTAL REACTIVE NITROGEN DEPOSITION FROM THE ATMOSPHERE (WET AND DRY) IN 1860, EARLY 1990S, AND PROJECTED FOR 2050



Source: Galloway et al. 2004

(milligrams of nitrogen per square metre per year) Atmospheric deposition currently accounts for roughly 12% of the reactive nitrogen entering terrestrial and coastal marine ecosystems globally, although in some regions, atmospheric deposition accounts for a higher percentage (about 33% in the United States) [R 9.1, Figure 9.2].

a depletion of oxygen (creating 'dead zones'), which reduces the survival of other marine organisms, including fish. There are several marine areas of low oxygen. Some of this variation can be clearly seen in the rates of nitrogen deposition, which are far higher in Europe, East and South Asia, eastern North America, and southeastern South America than elsewhere in the world [S 8.7; 9.3]. (See Figure 2.2.)

Eutrophication is pervasive close to most of the world's large estuaries and all centres of human population, and the resulting ecosystem changes are difficult (though perhaps not impossible) to reverse once algae take over benthic habitats or cause shifts in trophic structure [CT 19.2.1.1]. Maintenance of an adequate flow of good-quality water is needed to maintain the health of inland water ecosystems as well as estuaries and deltas [CT 20.6].

Agriculture is the major user of industrially fixed nitrogen, and only a fraction of this fertilizer is used and retained in food products [CT 26.2.1.4]. Poor control of run-off of the excess nitrogen leads to biodiversity loss in inland water, coastal, and marine systems through eutrophication [CT 19.2.1.4 and 26.2.1.4]. Nitrogen loads in rivers eventually find their way to the coastal zone, where they also cause eutrophication [S9.3.7.1.2]. Phosphorus transportation into aquatic ecosystems is the principal cause of blue-green algae blooms in reservoirs, and the anoxia in the Gulf of Mexico is one example of eutrophication attributable to nutrient enrichment [CT 26.2.2.3].

Sewers convey human waste out of urban locations, often releasing it untreated in local waterways or coastal waters. Human waste not only poses a health risk for people, who might ingest the contaminated water, but also causes eutrophication and damages aquatic ecosystems downstream [CT 27.2.3.2]. Other pollutants, such as persistent organic pollutants, accumulate in marine mammals, seabirds, top carnivores, and predatory fish and are passed on to humans through consumption. POPs are stable, fat-soluble, carbon-based compounds that volatilize at warm temperatures and are transported towards the poles by wind, water, and wildlife [CT 25.2.3].

Based on projections for food production and wastewater effluents, an increase of 10–20% of global river nitrogen flow to coastal ecosystems in the next three decades can be expected, following a global increase of 29% during the period 1970–95. In the Indian Ocean, the increase is likely to be faster than in the previous three decades; in the Pacific and Atlantic oceans, river nitrogen flow will continue to increase, but at a slower rate than in the last three decades in the Pacific and the Atlantic [S 9.3].

Climate Change

Climate change is becoming the dominant driver of change, particularly in vulnerable habitats such as mangroves, coral reefs, and coastal wetlands, which are especially at risk from resulting sea-level rises. Both recent empirical evidence and predictive modelling studies suggest that climate change will increase population losses [CT 4, Main Message #10]. For example, changes in the non-breeding distribution of coastal

rising mid-winter temperatures; and seabird breeding failures in the North Sea in 2004 have been linked to a northwards shift in plankton distribution driven by rising sea temperatures [CT 19.2.2.3].

Coral reefs are vulnerable due to coral bleaching (which sometimes causes coral mortality) and the spread of pathogens leading to the spread of coral diseases. It has been suggested that global warming will reduce the world's major coral reefs in exceedingly short time frames—one estimate suggests that all current coral reefs will disappear by 2040 due to warming sea temperatures [CT 19.2.1.4].

Changing wind patterns and sea temperatures impact oceanographic processes, including upwellings (for example, Benguela) and surface currents (for example, Gulf Stream), as well as nutrient availability affecting primary productivity. Recent results from monitoring of sea temperatures in the North Atlantic suggest that the Gulf Stream may be slowing down and affecting abundance and seasonality of plankton that are food for larval fish. Declining larval fish populations and lower adult fish stocks will impact the ability of overexploited stocks to recover [CT 18.3.1]. In the Arctic, regional warming interacts with socioeconomic change to reduce subsistence activities by indigenous and other rural people, the segments of society with the greatest cultural and economic dependence on natural resources. Warming has reduced access to marine mammals (less sea ice) by people dependent on subsistence activities and made the physical and biotic environment less predictable [CT 25, Main Message #5].

In the oceans, sea surface temperature increase reduces the solubility of CO_2 in the ocean and tends to increase vertical stratification (layering) and to slow down global ocean circulation. Stratification slows the mixing into deep layers of excess carbon in the surface water. Stratification further reduces nutrient input into the surface zone and leads to a prolonged residence time of phytoplankton at the surface, near light. Models indicate the net effect is reduced phytoplankton productivity. Models estimate that the combined effect of warming and circulation changes on ocean physics and biology will reduce the oceanic CO_2 uptake (that is, ability to absorb) by 6–25% in 1990–2050, thus providing a positive climate feedback (that is, increased warming) [CT 13.5.2].

Changes in ocean circulation, pH, and temperature are also likely to have additional effects on ocean biology that have not been quantified in these models and that may induce further CO_2 feedbacks. These include changes in the community structure, net production, and bio-calcification. The effect of bio-calcification is estimated to increase the ocean carbon sink by less than 2.5%. The quality and magnitude of biological changes will vary over space and time and is highly uncertain. While the combined inorganic and biological changes tend to reduce global uptake of anthropogenic carbon, the global net effect on carbon uptake of the ocean biological changes alone is unknown. Altered size and timing of phytoplankton blooms due to climate change can also potentially reduce fish production [CT 13.5.2].

Indirect Drivers of Change in Marine and Coastal Ecosystems

Demand, Fish Prices, and Shifting Food Preferences

Marine products are in demand as a luxury food, as a subsistence food source for many coastal communities, and as feed for aquaculture and livestock. Per capita consumption of fish is increasing rapidly—total fish consumption has declined somewhat in developed countries, while it has nearly doubled in the developing world since 1973 [CT 8, Main Message #9]. The growing demand and corresponding increase in prices has contributed to overfishing [CT 18.3.3].

Table 2.3 SHARE OF WORLD AND COASTAL POPULATIONS LIVING WITHIN 50 KILOMETRES OF ESTUARIES, CORAL REEFS, MANGROVES, AND SEAGRASS

Based on spatially referenced population data; due to overlap of some habitat types, figures do not add up to 100% [CT 19, Table 19.4].

Subtypes	Population	Share of World Population (%)	Share of Coastal Population (%)
Estuaries	1 598 940 542	27	71
Coral reefs	710 583 010	12	31
Mangroves	1 030 295 102	18	45
Seagrass	1 146 100 829	19	49
Total	5 996 803 192		

Persistent and widespread misconceptions about the ability of marine fish populations to withstand and recover from fishing continue to undermine initiatives to address the root causes of these problems [CT 18.3.8].

Subsidies

Financial subsidies are considered to be one of the most significant drivers of overfishing. The value of fisheries subsidies as a percentage of the gross value of fish production in the OECD area was about 20% in 2002 [CT 8.4.1.2.2]. In most cases, government subsidies have resulted in an initial increase of overall effort (number of fishers and size of fleet), which translates into increased fishing pressure and overexploitation of a number of species. While it appears that the number of fishing vessels and fishers stabilized in the late 1990s, other subsidies (for example, cheap fuel subsidies) can keep fleets operating even when fish are scarce. Without such subsidies, many of these fisheries would cease to be economically viable [CT 18.3.2].

Illegal Fishing

This practice exists due to high profits; lack of surveillance, enforcement, and monitoring; tolerance due to the economic conditions or social obligations within a country; and cheating in some fisheries that are supposedly regulated. It has led to the introduction of international on-board observers in some fisheries to attempt to bring an end to these. It is now widely agreed that independent surveillance is an essential part of any fishery management and enforcement plan [CT 18.3.6].

Population Growth

Human pressures stress many of the most ecologically important and valuable ecosystems within the coastal zones. (See Table 2.3.) This is not accidental, as these habitats and the ecosystems services they provide present many of the 'pull' factors that resulted in initial settlement on the coast as well as subsequent migration to it. Fifty-eight percent of the world's major coral reef systems occur within 25 km of urban centres greater than 100,000 people; 62% of major estuaries occur near such urban centres, and 64% of major mangrove forests occur near major centres. This means that pressures from urbanization, including habitat conversion as cities and their areas of influence grow, are affecting the majority of these key coastal habitats [CT 19.3.1].

Demand for fish as a food source and various other products from the sea are driven by population growth, human migration toward coastal areas, and rising incomes and hence demand for luxury seafood [CT 18.1]. There has been a decrease in the rate at which interior populations are increasing relative to coastal populations. If population growth is divided land area, we observe the highest value in the coastal zone, where over the 1990s population grew by 23.3 people per square kilometre [CT 5.3.4]. Coastal population densities are nearly three times that of inland areas: in 2000, population density in coastal areas was 99.6 people per km^2, while in inland areas density was 37.9 people per km^2. At the turn of the millennium nearly half (49.7%) of the world's major cities (having more than 500,000) people were found within 50 kilometres of the coast. Growth in these cities since 1960 was significantly higher than in inland cities of the same size. It is increasingly difficult for coastal ecosystems to accommodate the increased collective demands of growing populations and markets [CT 19.3.1].

Technology Change

The incorporation of an enormous array of electronic devices facilitating fish detection, including the introduction of radar and acoustic fish finders on fishing vessels, culminating with the introduction of GPS technology and detailed seabed mapping that occurred at the end of the cold war have contributed to overexploitation [CT 18.3.5].

Globalization

Fish represent the fastest growing food commodity entering international trade. Accordingly, fish and fish products represent an extremely valuable source of foreign exchange to many countries. Traditional local fish foods are, in many cases, no longer available to local consumers due to their inability to match the prices that can be obtained by shipping the products elsewhere. An example is Senegal, where exports have disrupted local supplies of fish [CT 18.3.7].

3 *Why should we care about the loss or degradation of marine and coastal ecosystems and their services?*

- Coastal areas are characterized by high productivity and high human well-being but also high vulnerability to natural disasters, diseases, and pollution. Island communities are particularly vulnerable to changes in marine and coastal services and habitat conditions.
- More than a billion people rely on fish as their main or sole source of animal protein, especially in the coastal zone of developing countries. The reliance and demand for food fish, the overcapacity of the global fleet, and overfishing results in declining food availability in the long term. Decreased availability of seafood and other resultant impacts of ecosystem services degradation have implications that reach far beyond the coastal zone.
- Fisheries and fish products provide direct employment to nearly 38 million people. The fishing sector has declined as a source of employment in many industrial countries, but in many developing countries and island communities there is still a strong traditional dependence on marine and coastal resources for employment.
- The global economic costs related to pollution of coastal waters is $16 billion annually, much of which is due to human health impacts.
- Other benefits—such as spiritual and cultural values and tourism—are threatened. Spiritual and cultural values are as important as other services for many local communities. Global tourism is one of the world's most profitable industries and much of it is linked to coastal and marine ecosystems.
- Coastal communities are at risk from a range of natural disasters. This risk increases as coastal and marine ecosystems are degraded.

Human Well-being and Ecosystem Services

Over historical time frames, human well-being has on aggregate improved by several orders of magnitude. Incomes have increased, populations have grown, life expectancies have risen, and political institutions have become more participatory. In the global aggregate, human well-being continues to expand, although there are variations across geographical regions.

Changes in ecosystem services influence all components of human well-being. The degradation of ecosystem services disproportionately affects the poor, although even wealthy populations cannot be fully insulated from the effects of degradation. The MA has defined well-being as the basic material needs for a good life, health, good social relations, security, and freedom of choice and action. Many of these elements of well-being are difficult to measure or are not measured adequately, often causing uncertainty or gaps in our understanding. (See Box 3.1.)

Coastal and marine ecosystems are among the most productive ecosystems in the world and provide a wide range of services to human beings. Coastal ecosystems tend to be characterized by high human well-being; however, coastal communities are at risk from natural disasters and diseases

Box 3.1 THE MA DEFINITION OF HUMAN WELL-BEING

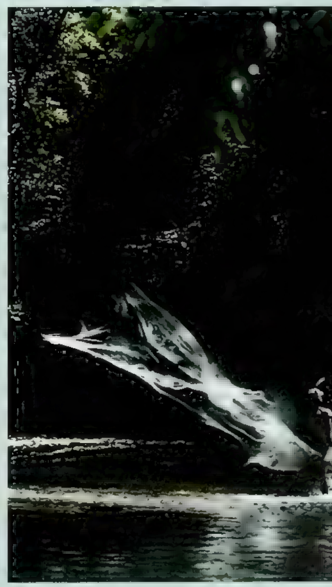
The basic materials for a good life include adequate income, household assets, food, water, and shelter. Considerable effort goes into measuring and monitoring these dimensions of well-being. Although great effort goes into these measurement efforts, they do not provide a complete enough picture to support a full understanding of the distribution of well-being and its relationship to ecosystem services [CT 5.2.1].

Freedom is defined as the range of options a person has in deciding on and realizing the kind of life to lead. At a broad scale, only a few of the many specific phenomena that are relevant to this dimension of well-being are measured at all, and many of those that are measured are problematic [CT 5.2.2].

Human health is measured in a variety of ways, and knowledge about broad trends and patterns concerning health is good. Life expectancy, infant mortality, and child mortality are measured fairly intensively [CT 5.2.3].

Humans enjoy a **state of good social relations** when they are able to realize aesthetic and recreational values, express cultural and spiritual values, develop institutional linkages that create social capital, show mutual respect, have good gender and family relations, and have the ability to help others and provide for their children [CT 5.2.4].

Humans can be said to live in a state of **security** when they do not suffer abrupt threats to their well-being. Some of the most salient threats are organized violence, economic crises, and natural disasters. Comparable measures of organized violence are available for international warfare and civil war, but generally not for banditry and other forms of crime. Natural disasters are not measured well, though various international organizations and research centres are seeking to improve measurement. The most glaring deficiency in efforts to measure natural disasters is in the area of human impacts. Although some insurance companies undertake considerable efforts to quantify insured economic losses due to natural disasters, many of the grossest effects on human well-being are not insured economic losses, but rather loss of life and shelter in poor communities [CT 5.2.5]. (Further information on natural disasters can be found in CT 6 and CT 16.)



[CT 5, Main Message #3]. Coastal inhabitants on average experience higher well-being than those of inland communities. Of the world's total gross national product of approximately $44 trillion, 61% comes from coastal areas within 100 kilometres of the coastline. Whereas per capita GNP in 1999 averaged only $4,018 across all inland areas, per capita GNP in the 100-kilometre coastal area was nearly four times as much at $16,035 globally. However, we should not lose sight of the fact that fishing communities in many developing countries are among the very poorest. Infant mortality and life expectancy indices are also thought to be relatively better in coastal areas. This situation partly explains why rates of population increase are highest in coastal areas [CT 19.3.1].

Marine and coastal ecosystems are also an important source of economic benefits, with capture fisheries alone worth approximately $81 billion in 2000; aquaculture $57 billion in 2000; offshore gas and oil $132 billion in 1995; marine tourism, much of it in the coast, $161 billion in 1995; and trade and shipping $155 billion in 1995. Much of this value comes from the overexploitation of marine and coastal ecosystems.

Basic Materials for a Good Life

Food Provision

More than one sixth of the world's population relies on fish as their main or sole source of animal protein. Global annual per capita consumption of seafood averages 16 kilograms. Fisheries are a particularly important source of protein in developing countries. The supply of wild marine fish as a cheap source of protein for many countries is declining. Annual per capita wild marine fish consumption in developing countries (excluding China) has declined from 9.4 kilograms per person in 1985 to 9.2 kilograms in 1997 [CT 18 Main Message #7].

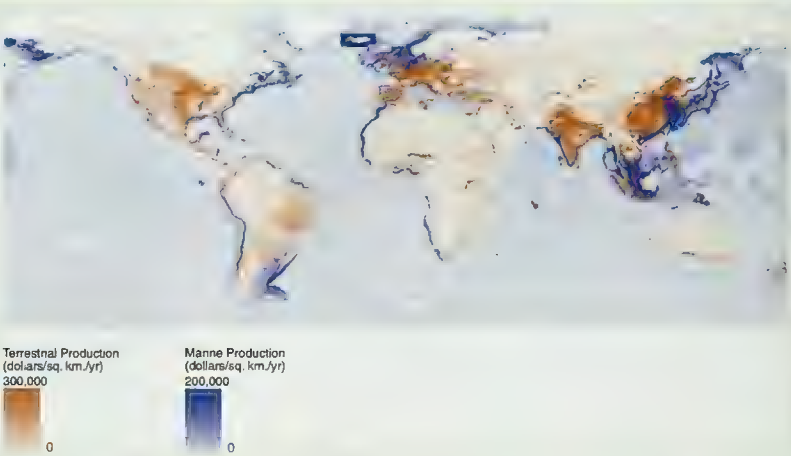
Overfishing threatens human well-being through declining food availability in the long term, since fewer fish are available for consumption and the price of fish increases. This is a particular issue in the developing world, where the combination of overfishing and degradation or conversion of habitats is aggravated by export-driven fisheries that overexploit their resource base, diverting food away from the domestic market [CT 18.5.1]. This is of major concern if the Millennium Development Goal of eradicating poverty and hunger (MDG 1) is to be achieved, as many areas where overfishing is a concern are also low-income food-deficit countries (LIFDCs). For example, in West Africa, the exclusive economic zones (EEZs) of Mauritania, Senegal, Gambia, Guinea Bissau, and Sierra Leone all accommodate large distant-water fleets, which catch significant quantities of fish.

Much of the fish is exported or shipped directly to Europe while compensation for access is often low compared to the value of the product landed [CT 18.4.1.4]. Similarly, in several small Caribbean islands, seafood consumption is higher than local production and must be satisfied by imports. This pattern holds true for countries such as Haiti (70% higher than local food production), Jamaica (78%), Martinique (80%). The composition of imports in these small island states is dominated by dried, salted, and smoked fish, but fresh, chilled, and frozen products are also imported, mainly by countries with a tourism industry [CT 23.2.2].

The decreased availability of marine fisheries can have implications that reach far beyond the coastal zone. For example, the decreased availability of coastal and freshwater fish for subsistence fisheries in West Africa has driven an increase in the illegal bush meat trade. This trade, in turn, has imperilled many endangered species in the region and is thought to contribute to outbreaks of primate-borne and other viruses in

Figure 3.1 SPATIAL DISTRIBUTION OF THE TOTAL VALUE OF FOOD PRODUCTION FOR CROPS, LIVESTOCK, AND FISHERIES IN 2000

Indicates where the major calorie and protein sources of the world are concentrated. Note the high production values of both marine and terrestrial food sources around Asia [CT 8, Figure 8.2].



human populations [CT 19.2.3]. Such long-distance connections are evident elsewhere in Africa. For example, the warming of the Indian Ocean has caused recent droughts in the Sahal, directly affecting millions of people through increased crop failure [CT 19.2.3].

Conflicts can arise between users with different property rights, largely driven by overexploitation of the resource. Marine ecosystems are often described as 'commons' (for everyone's use). While this may hold true for the open ocean, complex property rights exist in many coastal areas. The property rights in question can be traditional (aboriginal), historical/local, and commercial (that is, government sells the right to access resources). The boundaries between these rights are frequently unclear in the absence of effective management or enforcement and, in some cases, generate conflicts [CT 18.6]. For example, the small islands of the Pacific, Caribbean, and Indian oceans have narrow coastal shelves surrounded by deep waters. A simple fishing pressure index based on estimates of the number of people actively fishing (according to FAO) per kilometre of coastline suggests that fishing pressure is greatest in the China-Philippines area.

Overfishing in the near shore of these islands has led artisanal fishers to venture further offshore to access pelagic resources such as the large tunas. This has led to encounters and conflict with the already well-established industrial factory ships of more industrialized countries and/or other island states fishing in these waters using longlines or purse seines to exploit these resources. These conflicts over marine resources are increasingly being arbitrated through the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) [CT 23.2.2].

Another example is the growth of shrimp farming and the consequent damage of such aquaculture on mangroves (see CT 19.). In Honduras, social conflict has increased between shrimp farm concession holders and those who are not concession holders but believe that shrimp farms are intruding on government-reserved natural resources [CT 5.5].

The ecosystem service of food production contributes by far the most to economic activity and employment. In 2000, the market value of global food production was $981 billion, or roughly 3% of gross world product (although it is a much higher share of GDP within developing countries). Of this, marine and coastal fisheries (wild and aquaculture) contribute $124.2 billion, or 12% of world food production [CT 8, Table 8.1].

Poor people historically have lost access to ecosystem services disproportionately as demand for those services has grown. Coastal habitats are often converted to other uses, frequently for aquaculture ponds or cage culturing of highly valued species such as shrimp and salmon. Despite the fact that the area is still used for food production, local residents are often displaced, and the food produced is usually not for local consumption but for export [CT 18.5.1]. However, food production in terrestrial ecosystems is higher than in marine ecosystems. (See Figure 3.1.)

Fish products are heavily traded, and approximately 50% of exports are from developing countries. Exports from developing countries presently offset much of the shortfall of supply in European, North American, and East Asian markets [CT 18.4.1.4]. Trade has increased the quantity and quality of fish supplied to wealthy countries, in particular the United States, European countries, and Japan, despite reductions in marine fish catch [CT18.4.1.1].

Employment

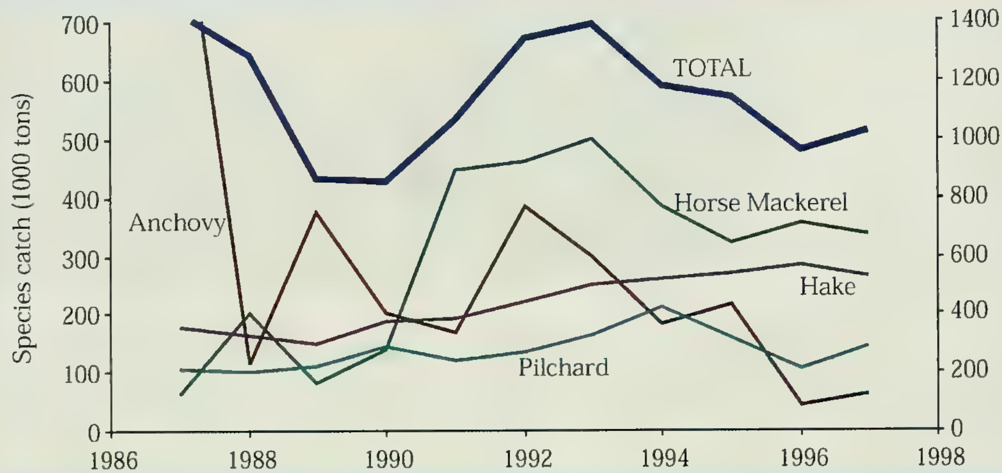
Fisheries and fish products provide direct employment to nearly 38 million people (FAO 2004), with approximately 15 million fishers employed aboard decked and undecked fishing vessels in the marine capture fisheries sector [CT 18.1]. However the fishing sector has declined as a source of employment in many industrial countries [CT 18.4.1]. For example, in Canada, the collapse of the cod fishery resulted in severe unemployment compounded by restrictions on subsistence fishing [18.5.1].

Although the fishing sector has declined as a source of employment in many industrial countries, many developing countries and small island communities still have a strong traditional dependence on marine and coastal biodiversity for

Box 3.2 THE BENGUELA FISHERY [SAfMA sub-global assessment, Box 5.5]

The Benguela fishery lies almost entirely within the economic zone of three countries: South Africa, Namibia, and Angola. These countries cooperate closely in the management of fish stocks to ensure that they persist. A contributing factor to the longevity of the fishery is its dependence on small pelagic fish, which live for a year and recruit annually in large numbers, compared to fisheries based mostly on high-trophic-level, long-lived fish.

Following the inception of commercial fisheries during the early twentieth century, and especially from about mid-century, the combined catch of the five main species in the Benguela system grew to a peak around 1970 and then declined. In recent years, many of the stocks have shown a gradual recovery. However, the collapsed anchovy and pilchard stocks off Namibia have not recovered. Several marine fish species harvested on the west coasts have shown large fluctuations in the stock (see Figure), the causes of which are poorly understood. In the case of the Namibian anchovy, the increasing frequent southward intrusion of warm tropical water, a phenomenon similar to (but apparently unconnected with) the El Niño in the Pacific Ocean, may be associated with their decline. In the case of the other species, overfishing is the probable main factor causing the fluctuations.



Trends in Marine Fish Catches in the Benguela Large Marine Ecosystem (LME) off the west coast of Southern Africa. This system provided 44% of the total catch in the region during the 1990s. The fluctuation in stocks appears to be synchronized with stock fluctuations in other major fisheries around the world, and is therefore suggested to be partly influenced by the climate system [CT 8, Figure 8.2].

employment. The reliance on and demand for food fish, the overcapacity of the global fleet, and overfishing result in declining food availability in the long term. (See Box 3.2.)

The early 1990s collapse of the Newfoundland cod fishery (see Figure 3.2) due to overfishing resulted in the loss of tens of thousands of jobs and has cost at least $2 billion in income support and retraining [General SR 3]. Globally, the bulk of people employed in fisheries are poor and many are without alternative sources of work and subsistence.

Tourism also is a major source of coastal employment. Loss of habitat can impact heavily on local employment. For example, the total damages for the Indian Ocean region over 20 years (with a 10% discount rate) resulting from the long-term impacts of massive coral bleaching in 1998 are estimated to be between $608 million (if there is only a slight decrease in tourism-generated income and employment results) and $8 billion (if tourism income and employment and fish productivity drop significantly and reefs cease to function as a protective barrier).

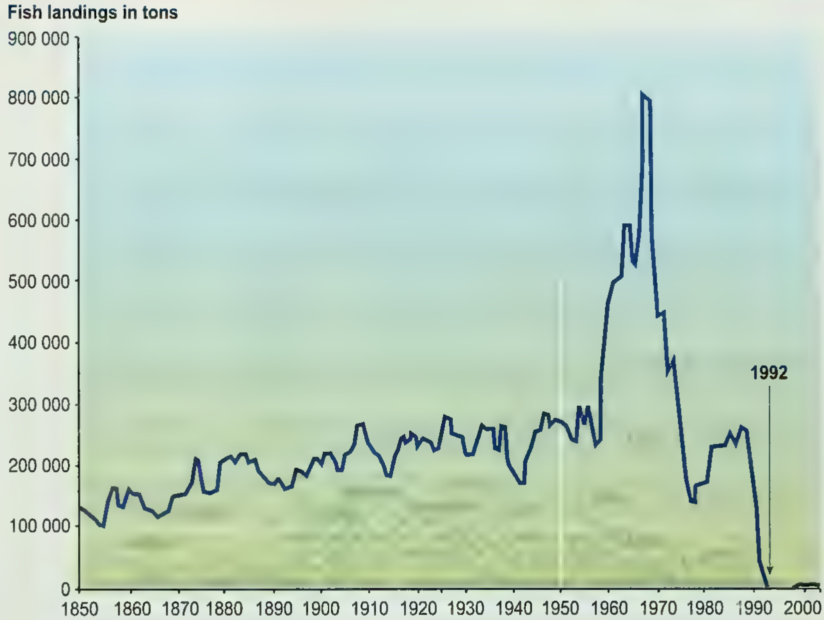
Other Marketable Goods

A global picture of the potential economic value associated with the coastal zone can be built up by aggregating a number of existing valuation studies. A preliminary estimate of the total economic value of ecosystem services provided by global ecosystems showed that while the coastal zone covers only 8% of the world's surface, the goods and services provided by it are responsible for approximately 43% of the estimated total value of global ecosystem services: $12.6 trillion (1997 dollars). While controversial, this preliminary study made it abundantly clear that coastal ecosystem services do provide significant contribution to human well-being at a global scale. Furthermore, it demonstrated the need for additional research and indicated the fact that coastal areas are among the ecosystems most in need of additional study [CT 19.3.2].

Coastal ecosystems provide other types of marketable goods such as genetic, medical, and ornamental (aquarium trade) resources. Coral reefs have been shown to be an exceptional

Figure 3.2 COLLAPSE OF ATLANTIC COD STOCKS OFF THE EAST COAST OF NEWFOUNDLAND IN 1992

This collapse forced the closure of the fishery after hundreds of years of exploitation. Until the late 1950s, the fishery was exploited by migratory seasonal fleets and resident inshore small-scale fishers. From the late 1950s, offshore bottom trawlers began exploiting the deeper part of the stock, leading to a large catch increase and a strong decline in the underlying biomass. Internationally agreed quotas in the early 1970s and, following the declaration by Canada of an Exclusive Fishing Zone in 1977, national quota systems ultimately failed to arrest and reverse the decline. The stock collapsed to extremely low levels in the late 1980s and early 1990s, and a moratorium on commercial fishing was declared in June 1992. A small commercial inshore fishery was reintroduced in 1998, but catch rates declined and the fishery was closed indefinitely in 2003 [General SR, Figure 3.4].



Source: Millennium Ecosystem Assessment

reservoir of natural bioactive products, many of which exhibit structural features not found in terrestrial natural products [CT 19.3.2.1].

Biological monitoring is an industry developing in response to the necessities of tracking down sources of pollution across large geographical areas. This would normally require vast resources in terms of conventional instrumentation but the status of the environment can also be monitored by using organisms that routinely 'sample' the environment, such as aquatic or marine filter-feeding animals (for example, paddle worms, sea squirts) [CT 10.2.7].

Some marine species have been overharvested for natural products research such as cone shells of the molluscan family Conidae for their highly variable toxins (conotoxins) for application to many areas of medicine [CT 10.7.4].

The market price of seafood products is often used as a proxy when calculating the value of ecosystems. The annual market value of seafood supported by mangroves, for example, has been calculated to range from $750 to $16,750 (1999 dollars) per hectare [CT 19.3.2.1]. The wide range indicates the varying importance of different seafood and is not an accurate indication of the worth of mangroves. Due to their function as nurseries, fisheries yields in waters adjacent to mangroves tend to be high; annual net values of $600 per hectare per year for this fishery benefit have been suggested [CT 19.2.1.2]. Coral reef-based fisheries are also valuable: the coral reef-based fisheries in Southeast Asia, for example, generate $2.4 billion per year.

Mangrove forests are estimated to provide an annual net benefit of $15 per hectare for medicinal plants, and up to $61 per hectare for medicinal values. Similarly large economic benefits are calculated for the shoreline stabilization and erosion control functions of mangroves [CT 19.2.1.2].

Human Health

Human communities are also at risk from the health implications of degraded ecosystems. Cholera and other waterborne diseases are on the rise in coastal countries, and may be related to declining water quality, climate, and eutrophication-driven algal blooms. Algal blooms (including red tides) have caused neurological damage and death in humans through consumption of affected seafood. The toxins in red tide species may be accumulated in marine organisms and cause a number of different types of toxic effects to humans [CT 19.3.1]. The incidence of diseases of marine organisms and emergence of new pathogens is increasing, and some of these, such as ciguatera, harm human health [CT 19.3.1]. Cholera impacts human well-being directly by increasing human morbidity and mortality rates, but it also has severe economic impacts in coastal countries. For instance, tuna coming from countries having incidences of cholera are required to be quarantined; this restriction affects many of the major tuna producing and exporting countries [CT 19.3.1].

Human health effects are also caused by pollution of

nearshore waters, whereby humans consume fish or other marine products that contain heavy metals, PCBs, POPs, and other toxins that have bioaccumulated in the food chain. Chronic exposure to heavy metals and other bioaccumulating pollutants may not cause death in large numbers of people, but their cumulative effect can lead to reproductive failure and significantly decreased well-being [CT 19.3.1]. UNEP and the Water Supply and Sanitation Council estimate the global economic costs related to pollution of coastal waters is $16 billion annually (www.wsscc.org), much of which is due to human health impacts [CT 19.3.1]. Coastal waters in both industrial and developing countries are frequently contaminated with sewage [CT 14.2.1.5].

Good Social Relations

Spiritual and Cultural Values

Spiritual and cultural values of ecosystems are as important as other services for many local communities. Human cultures, knowledge systems, religions, heritage values, and social interactions have always been influenced and shaped by the nature of the ecosystem and ecosystem conditions in which culture is based. People have benefited in many ways from cultural ecosystem services, including aesthetic enjoyment, recreation, artistic and spiritual fulfilment, and intellectual development [CT 17, Main Messages].

The degradation of marine and coastal habitats affects the well-being of all people in many ways that cannot be measured in economic terms. Open space, proximity to clean water, and scenic vistas are often cited as primary attractors of residents who own property and live within the coastal fringe. Even for people who live far inland with no direct reliance on coastal areas, surveys show that humans maintain strong spiritual connections to the sea and care about its condition. Additionally, for many cultures, such as First Nations of the Pacific Northwest of North America, coastal species such as salmon are of considerable importance and often define the 'quality of life' of people with a cultural tradition of harvesting the sea [CT 18.4.1.2].

Tourism and Recreation

Natural amenities are highly valued by people and contribute to human welfare, thus providing significant economic value. Much of what people value in the coastal zone—natural amenities (open spaces, attractive views), good beaches for recreation, high levels of water quality, protection from storm surges, and waste assimilation/nutrient cycling—are provided by key habitats within coastal ecosystems. Stretches of beach, rocky cliffs, estuarine and coastal marine waterways, and coral reefs provide numerous recreational and scenic opportunities. Boating, fishing, swimming, walking, beachcombing, scuba diving, and sunbathing are among the numerous leisure activities that people enjoy worldwide and thus represent significant economic value [CT 19.3.2.2]. The seas and coasts are also of great spiritual importance to many people around the world, although such values are difficult to quantify. For example, the Bajau peoples of Indonesia and the aboriginal people of the Torres Strait (Australia) have a culture intimately connected to oceans, while many of the native peoples of North America have similar strong ties to coastal ecosystems [CT 19.3.2.2].

Reef-based tourism generated over $1.2 billion annually in the Florida Keys (of the United States) alone and the Great Barrier Reef (Australia) attracts 1.6 million visitors each year and generates over $1 billion annually in direct revenue [CT 18.6]. Much of this tourism centres on aesthetically pleasing landscapes and seascapes; intact healthy coastal ecosystems with good air and water quality; and opportunities to see diverse wildlife. Tourism and recreational values are particularly high for semi-enclosed seas, many of which are becoming highly degraded (for example, Gulf of California, Black Sea, Baltic Sea, and large parts of the Mediterranean Sea). Many of the world's great civilizations sprang up along the shorelines of these seas, and thus they have historically provided food, trade routes, and waste processing services to their burgeoning populations [CT 19.2.1.8]. Harmful algal blooms, including red tides, can be quite costly in these areas. For example, a bloom in 1989 cost the Italian tourism industry $11.4 million [CT 19.3.1]. Another important activity associated with tourism is recreational

Box 3.3 ISLAND ECOSYSTEM CASE STUDY

Island communities are particularly vulnerable to changes in marine and coastal services and habitat conditions. Many small islands have a strong traditional dependence on marine and coastal biodiversity for their food, employment, tools, building materials, industry, medicine, transport, and waste disposal. With increasing human population pressures through high migration and reproductive rates, island ecosystems face several serious issues both in the immediate and near future [CT 23, Main Message #1]. Overfishing has already deprived island communities of subsistence fishing and caused conflicts in many tropical islands across Asia. Island states and their exclusive economic zones comprise 40% of the world's oceans and earn significant foreign exchange from the sale of offshore fishery licences, but this situation cannot last forever [CT 23, Main Message #3]. One of the most important roles of fisheries in island states is the employment opportunities it offers for thousands of people in a region where high levels of unemployment continue to be a major concern. The fisheries sector on small island developing states in the Caribbean provides stable full-time and part-time direct employment for more than 200,000 people and indirect employment for another approximately 100,000 people in the secondary sector (processing, marketing), boat building, net making, and other support industries [CT 23.2.2]. Islands also face increased problems of coastal and beach erosion due to inappropriate forms of coastline engineering and tourism development that often use coral and beach sand as building material [CT 23.3.3].

fishing. For example, there is a growing population of recreational fishers within the Caribbean where dozens of international, regional, and national fishing tournaments are held each year [CT 23.2.5.2].

Much of the economic values of coral reefs (with net benefits estimated at nearly $30 billion each year) are generated from nature-based and dive tourism. Coral reef-based recreational fisheries generate over $100 million annually. The annual recreational value of the coral reefs of each of six Marine Management Areas in the Hawaiian Islands in 2003 ranged from $300,000 to $35 million [General SR 3]. 'Willingness to pay' studies in the Indian Ocean suggest that health of coral reefs is an important factor for tourists: tourists were willing to pay, on average, $59-$98 extra per holiday to experience high-quality reefs. In Jamaica and Barbados, destruction of coral reefs has resulted in dramatic declines in visitation; loss of revenue streams subsequently led to social unrest and even further tourism declines (MA Subglobal Assessment—Caribbean Sea). In Florida, reef degradation is rapidly changing the structure of the tourism market, from high-value, low-volume tourism towards larger numbers of budget travellers [CT 19.3.2.2].

Despite the value of coastal areas to the tourism industry, coastal tourism development also contributes to the continued degradation of these ecosystems. For example, it often uses habitats such as estuaries, mangroves, marshes, and atoll lagoons for waste disposal, reducing their capacity to provide ecosystem services such as waste processing and coastal protection. Tourism development also results in conversion of habitat to accommodate infrastructure, resulting in loss of dune systems, wetlands, and even coral reefs [CT 19.4.1].

Security

Natural Disasters

Coastal communities are at risk from natural disasters such as hurricanes, cyclones, tsunamis, and storm surge flooding, as well as losses incurred from both sudden and chronic shoreline erosion. Losses of habitats such as mangrove forests (35% have disappeared in the last two decades) threaten the safety of people living in the 118 coastal countries where mangroves occur. Mangroves not only serve as a buffer from storm damage for these communities, but also serve to absorb heavy metals and other toxic substances in effluents [CT 19.2.1.2]. Projected sea-level rise due to climate change (1–2 mm/yr over the next century) is expected to have serious consequences for millions of people living on low-lying islands, atolls, or flood-prone areas like much of Bangladesh [CT 19.3.1] through the effects of flooding and coastal erosion. In turn, flooding and coastal erosion will have serious consequences for the tourism industry [CT 23, Main Messages #9].

Erosion

A fifth of the coastline of the newly enlarged European Union is eroding away due to human-induced causes, in a few cases as much as 15 metres (49 feet) shoreline erosion inland per year. Erosion threatens homes, roads and urban infrastructure, and the safety of individuals, and affects biodiversity as well [CT 19.6]. Coastal erosion can have significant economic consequences. For example, in the United States alone, coastal erosion of dunes and beaches costs $500 million in property loss annually [CT 19.2.1.3].

Box 3.4 POLAR REGION CASE STUDY

In polar regions, products derived from locally available fish and wildlife resources often offer important sources of cash that supplement wages and transfer payments from governments. However, subsistence economies are vulnerable to declines in global markets for these commodities; examples include seal or muskrat pelts (as changes in cultural values reduced global demand for furs), salmon (as fish farming increased alternative supplies), and reindeer antler (as cultural change in Asia reduced demand). When world market prices are high, regional resource management institutions may be unable to respond to the increased incentives for unregulated or illegal harvest (for example, Kamchatka salmon, Greenland cod) or overgrazing by reindeer. On the other hand, government policies to conserve stocks may prevent Arctic people from taking advantage of the only viable commercial activities available (as with the International Whaling Commission ban on commercial whaling) [CT 25.4.2].

Trade-offs between Conservation and Other Priorities

Trade-offs in meeting Millennium Development Goals and other international commitments are inevitable. There is strong evidence that the condition of inland waters and coastal ecosystems has been compromised by the conventional sectoral approach to water management and, if continued, will jeopardize human well-being. In contrast, through implementation of the established ecosystem-based approaches adopted by the Convention on Biological Diversity, the Convention on Wetlands (Ramsar), FAO, and others, the future condition of water provisioning services could be substantially improved by balancing economic development, ecosystem preservation, and human well-being objectives [CT 7, Main Message #6].

A 'business as usual' approach is projected to lead to continued loss of habitats and species, with attendant changes to ecosystem services and negative impacts on many coastal-dependent industries and coastal communities. Yet enough is known to change the current approach and begin to systematically develop strategic plans for more effective protection and more sustainable use of coastal ecosystems [CT 19.6].

Boxes 3.3 and 3.4 demonstrate some of the vulnerabilities for two particular marine influenced regions.

Gaps in Understanding regarding Human Well-being

Human well-being depends on ecosystem services but also on the supply and quality of social capital, technology, and institutions. These factors mediate the relationship between ecosystem services and human well-being in ways that remain contested and incompletely understood. The relationship between human well-being and ecosystem services is not linear. When an ecosystem service is abundant relative to the demand, a marginal increase in ecosystem services generally contributes only slightly to human well-being (or may even diminish it). But when the service is relatively scarce, a small decrease can substantially reduce human well-being [SG 3.4].

The degradation of ecosystem services represents a loss of a capital asset. Both renewable resources such as ecosystem services and nonrenewable resources such as mineral deposits, soil nutrients, and fossil fuels are capital assets. Yet traditional national accounts do not include measures of resource depletion or of the degradation of renewable resources. As a result, a country could cut its forests and deplete its fisheries, and this would show only as a positive gain to GDP despite the loss of the capital asset. Moreover, many ecosystem services are available freely to those who use them (freshwater in aquifers, for instance, or the use of the atmosphere as a sink for pollutants), and so, again, their degradation is not reflected in standard economic measures [General SR 3].

The information available to assess the consequences of changes in ecosystem services for human well-being is relatively limited. Many ecosystem services have not been monitored and it is also difficult to estimate the relative influence of changes in ecosystem services in relation to other social, cultural, and economic factors that also affect human well-being [General SR 3].

Box 3.5 THE MA SCENARIOS [Biodiversity SR]

It is important to remember that no scenario will match the future as it actually occurs. None of the scenarios represents a 'best' path or a 'worst' path. There could be combinations of policies and practices that produce significantly better or worse outcomes than any of these scenarios. The future will represent a mix of approaches and consequences described in the scenarios, as well as events and innovations that could not be imagined at the time of writing [S 5].

The focus on alternative approaches to sustaining ecosystem services distinguishes the MA scenarios from previous global scenario exercises. The four approaches were developed based on interviews with leaders in NGOs, governments, and business on five continents, on scenario literature, and on policy documents addressing linkages between ecosystem change and human well-being. The approach to scenario development used in the MA consists of a combination of qualitative storyline development and quantitative modelling based on assumptions about the evolution of indirect drivers such as economic and population growth [S 6].

The **Global Orchestration** scenario explores the possibilities of a world in which global economic and social policies are the primary approach to sustainability. The recognition that many of the most pressing global problems seem to have roots in poverty and inequality evokes fair policies to improve the well-being of those in poorer countries by removing trade barriers and subsidies. Environmental problems are dealt with in an ad-hoc reactive manner, as it is assumed that improved economic well-being will eventually create demand for, and the means to achieve, environmental protection. Nations also make progress on global environmental problems, such as greenhouse gas emissions and the depletion of pelagic marine fisheries. However, some local and regional environmental problems are exacerbated. The results for ecosystem services are mixed. Human well-being is improved in many of the poorest countries (and in some rich ones), but a number of ecosystem services deteriorate by 2050, placing at risk the long-term sustainability of the well-being improvements.

The **Order from Strength** scenario examines the outcomes of a world in which protection through boundaries becomes paramount. The policies enacted in this scenario lead to a world in which the rich protect their borders, attempting to confine poverty, conflict, environmental degradation, and deterioration of ecosystem services to areas outside the borders. These problems often cross borders, however, impinging on the well-being of those within.

The **Adapting Mosaic** scenario explores the benefits and risks of environmentally proactive local and regional management as the primary approach to sustainability. In this scenario, lack of faith in global institutions, combined with increased understanding of the importance of resilience and local flexibility, leads to approaches that favour experimentation and local control of ecosystem management. The results are mixed, as some regions do a good job managing ecosystems but others do not. High levels of communication and interest in learning lead regions to compare experiences and learn from one another. Gradually the number of successful experiments begins to grow. While global problems are ignored initially, later in the scenario they are approached with flexible strategies based on successful experiences with locally adaptive management. However, some ecosystems suffer long-lasting degradation.

The **TechnoGarden** scenario explores the potential role of technology in providing or improving the provision of ecosystem services. The use of technology and the focus on ecosystem services is driven by a system of property rights and valuation of ecosystem services. In this scenario, people push ecosystems to their limits of producing the optimum amount of ecosystem services for humans through the use of technology. Often, the technologies they use are more flexible than today's environmental engineering, and they allow multiple needs to be met from the same ecosystem. Provision of ecosystem services in this scenario is high worldwide, but flexibility is low due to high dependence on a narrow set of optimal approaches. In some cases, unexpected problems created by technology and erosion of ecological resilience lead to vulnerable ecosystem services, which may break down. In addition, success in increasing the production of ecosystem services often undercuts the ability of ecosystems to support themselves, leading to surprising interruptions of some ecosystem services. These interruptions and collapses sometimes have serious consequences for human well-being.

The reliance of the rural poor on ecosystem services is rarely measured and thus typically overlooked in national statistics and in poverty assessments, resulting in inappropriate strategies that do not take into account the role of the environment in poverty reduction [General SR 3].

A Look at the Future: The Four MA Scenarios

The MA explores the future for ecosystem services and human well-being through four different plausible scenarios. Scenarios are a means to explore future changes that are difficult to describe using the extrapolation of known current or past trends to analyse how ecosystems might respond to different future policy regimes and a range of drivers affecting ecosystems and human well-being. The four scenarios—Global Orchestration; Order from Strength; Adapting Mosaic; and TechnoGarden—cover a wide range of possible developments for the years up to 2050. (See Box 3.5.) It is likely that the real future will not mirror one of the scenarios but will rather consist of a mix of the elements of all four scenarios.

Cross-cutting Issues across the Four Scenarios

Due to the lack of basic information on marine and coastal ecosystems, the MA scenarios cover only some of the major drivers of change in those ecosystems. The following sections explore those changes for some factors affecting ecosystem change and ecosystem services. Fisheries, eutrophication, and climate change (with the accompanying sea-level rise and coastal protection) are amongst the strongest drivers (see Chapter 1 for information on other drivers), while biodiversity is a fundamental key ecosystem service in the coastal and marine realm. Box 3.6 highlights the major predictions of the scenarios.

Box 3.6 PREDICTIONS FROM THE MA SCENARIOS

All scenarios predict:

- **An increase in demand for fish for food and a massive decline, if not a collapse, of the major fish stocks over the next decades.** The decline of fish stocks under the scenarios in the next decades is of major concern and will impact upon achieving Millennium Development Goal 1, eradication of extreme poverty.

- **Climate-change-induced sea-level rise.** The scenarios variously predict a 50–70 cm rise with a further rise in the next century. Sea-level rise is expected to have severe impacts for coastal communities under all scenarios except the Adapting Mosaic scenario. As poverty is concentrated in the coastal zone, this will have repercussions for MDG 1.

- **Increase in eutrophication of coastal and marine ecosystems.** The scenarios differ in their ability to address dead zones of hypoxia.

Cross-cutting Issue 1: Fisheries

Across all four scenarios, an increase in the demand for fish as food is forecasted, accompanied by a decline of fish stocks that differs among the scenarios. The forecasts for industrial and developing countries differ substantially. Uncertainties in the interpretation of recent fish stock trends make forecasting difficult.

A range of factors will determine future wild capture fisheries. They include changes in the degree of overfishing due to fisheries mismanagement; fishing subsidies affecting the catch at the fisheries level; climate and climate variability, causing shifts in species distributions and abundance; and population growth and food preferences affecting the demand for marine products [S 9.4.3]. Other interactive effects are also occurring, such as eutrophication and coastal development.

In the Global Orchestration scenario, many of the world's major fisheries collapse between 2030 and 2050. The scenario expects some global cooperation in managing species, but open borders and reduced trade barriers would lead to insurmountable obstacles to effective monitoring of many stocks, which would be exploited unsustainably and severely overfished [S 8.3]. However, economic incentives, regulation, and the creation of marine protected areas help to establish sustained catches in some areas of industrial countries. This also applies to some developing countries with stable governance, but the race against climate changed-induced degradation of coral reefs and other marine areas does hamper such efforts. Illegal fishing, corruption, and lack of enforcement lead to overexploitation of fish stocks in developing countries with poor governance.

High-seas fisheries are expected to rise in importance under the Global Orchestration scenario, driven by industrial countries. This relates mainly to pelagic sources, while deep-sea

fisheries on seamounts and deep-sea corals cease. Many more high-seas marine protected areas will finally become established.

Coastal aquaculture is forecasted to expand in both industrial and developing countries. In the latter more than the former, aquaculture is accompanied by negative impacts on the environment and small-scale coastal fisheries. High-seas aquaculture is slowly on the rise, with costs for technological development limiting its expansion during the first decades of the 21st century. Conflicts about access rights on the high seas ultimately lead to the formation of a global oceans commission [S 8.7].

In the Order from Strength scenario, global issues such as climate change or marine fisheries are very difficult to address. Hence, climate change, sea-level rise, and events such as the El Niño/Southern Oscillation severely impact the fishing options for poor countries and, within those, in particular the poor coastal communities. While global agreements become almost impossible to establish, some regional agreements succeed in providing protection for fish stocks, mainly in regions of industrial countries and regions that receive assistance from those. This would include, to a limited extent, the closure of areas to fisheries and the formation of marine protected areas. These industrial countries reduce their outflow of fish products to secure food security and social benefits within their own boundaries.

In the scenario, aquaculture expands rapidly, bearing high costs for biodiversity, coastal protection, and related ecosystem services. The lack of control of high-seas fisheries leaves high-sea fish stocks unprotected and, hence, stocks reach the stage of collapse rather quickly [S 8.4; S 8.7].

Under the Adapting Mosaic scenario, the world fish catch may decline severely by 2020—the tragedy of the Global Commons. Coastal communities and those depending on marine resources in developing countries suffer from the decline in protein supply. In the longer term, however, industrial countries manage to improve conditions of marine and coastal ecosystems, through phasing-out of destructive fishery practices, formation of marine protected areas, and construction of artificial coral reefs. Some developing countries, through assistance from regional bodies and some industrial countries, achieve stabilization of coastal and marine ecosystems, while countries with poor governance face further stock collapses. Top predators are likely to vanish from most marine ecosystems.

Aquaculture will only slowly expand in industrial countries and those developing countries with good governance, due to the reliance on wild-caught fishmeal. In developing countries with poor governance, aquaculture may be likely to be forced to expand, but the high economic costs, accompanied by major impacts on ecosystem services, eventually lead to it being abandoned.

Further expansion of fisheries into the high seas is not controlled, due to the lack of global agreements. But the high costs eventually limit high-seas fisheries, particularly for those industrial countries that manage to develop sustainable near-coast fisheries and freshwater aquaculture [S 8.5].

The TechnoGarden scenario forecasts an increased regulation of high-seas fisheries, addressing the severe stock declines. Ranching of important fish such as tuna helps in managing the stocks. The focus on global solutions tends to leave small-scale fisheries neglected, and local resource users are in danger of losing their income. In industrial countries, fishery practices are improved with the help of technology. This is particularly relevant for high-value fish for food species such as large shrimp, salmon, and cod. Technology allows for a massive expansion of aquaculture, with less and less need for wild-caught fishmeal and the development of feed alternatives.

Box 3.7 CASE STUDY: FISHERIES AND TOURISM IN THE CARIBBEAN SEA—JAMAICA AND BONAIRE [S 12.4.3]

Many ecosystem services are provided by the Caribbean Sea. Two of the most prized are fisheries and recreation. The Caribbean attracts about 57% of scuba diving tours worldwide. In the 1950s, 1960s, and 1970s, Jamaica was the prime dive location, and hard corals covered as much as 90% of shallow coastal areas. By the late 1960s, chronic overfishing had reduced fish biomass by about 80% compared to the previous decade. Then, in the early 1980s, two extreme events hit Jamaican coral reefs, causing their collapse. In 1980, Hurricane Allen broke many large elkhorn and staghorn corals into pieces. In 1983, an unidentified disease spread throughout the Caribbean and killed 99% of black spined sea urchins (*Diadema antillarum*), the primary grazer of algae on the reefs. Without the ecosystem services provided by grazing fish or sea urchins, fleshy macro-algae came to dominate coral reefs (more than 90% cover) in just two years. The lucrative dive tourism industry in Jamaica declined.

When the sea urchin mass mortality occurred throughout the region, most sites suffered algal overgrowth, but a few sites—like Bonaire—did not. With abundant grazing fish, Bonaire had no reported algal overgrowth. In Bonaire, the Reef Environmental Educational Foundation has recently generated statistics from about 60,000 coral reef fish surveys, which rate seven dive sites in Bonaire among the top 10 worldwide for fish species richness, with over 300 species. Bonaire banned spear fishing from its reefs in 1971. In 1979, the Bonaire Marine Park was created. In 1992, active management of the park started with the introduction of mandatory permits for divers, bringing in about $170,000 a year to support protected area management. Economic activities (dive operators, hotels, etc.) connected with the park attract about 10,000 people annually; such activities are valued at over $23 million per year. In contrast, the cost of park management is under $1 million per annum. In this case, regulating provision of one service (the fishery) maintained resilience in the ecosystem and led to a long-term gain in provision of recreation as well as a stable, long-term fishery. These synergistic interactions among ecosystem services allow for the simultaneous enhancement of the supply of more than one ecosystem service.

CONSEQUENCES OF EACH SCENARIO FOR THE FACTORS AFFECTING HYPOXIA IN THE GULF OF MEXICO [S 8, Table 8.8]

FACTOR	[illegible]	[illegible]	[illegible]	[illegible]
Farming	Decrease in area; no change in nutrients; some improvement in land management; constant or minor decrease in nutrient runoff	Increase in area; increase in fertilizer use; limited improvement in land management; increased nutrient runoff	Increase in area; less fertilizer use; better land management practices; less nutrient runoff	Decrease in area; less fertilizer use; better land management practices; less nutrient runoff
Managing the river	Management of river for barges eliminates some wetlands and increases channelization; some increase in wetlands and buffers elsewhere; no change in proportion of nutrients entering Mississippi	Some local addition of riparian buffers and wetlands combined with decrease in wetlands and building levees; increased proportion of nutrients entering Mississippi	Some levee removal driven by farming and flood protection; restored wetlands and riparian buffers; decreased proportion of nutrients entering Mississippi	Levee removal and re-engineering of floodplains with ecologically sophisticated levees and engineered wetlands; decreased proportion of nutrients entering Mississippi
Managing the river delta	Investment in human well-being in delta results in many local improvements; however, river channelization leads to only small increases in flow through delta	Some area abandoned; regulation of river; further decrease in delta despite some local increases in wetland	Local projects, but disagreements about what to do about the river; slightly increased flow through the delta	Federal ecological re-engineering of the delta leads to greatly increased area of wetlands
Changes in hypoxia	Slow growth in area	Substantial growth in area	Initial increase in area, then gradual decline	Reduction in area
Changes in fishery	Sport fishery persists, commercial fishery closed due to low profitability	Fishery eliminated	Local management and improvement of fishery	Fishery increased and combined with delta; aquaculture maintained

Offshore aquaculture is developed for high-value fish such as tuna. Technological solutions, however, remain vulnerable to surprise events such as the spread of diseases and pests. Corporations from the industrial world take over substantial parts of developing-country fisheries, which export large amounts to the developed world. International aid is required to support the collapsing fishing communities in developing countries. The expansion of aquaculture counters this impact to some extent. Aquaculture in the developing world focuses more on lower-value fish, to support food security and provide cheap export products. Large tracks of coastal land are lost to aquaculture, with impacts on ecosystem services such as erosion control and storm and flood protection.

High-seas fisheries face further losses of stocks and tend increasingly to focus on aquaculture operations outside of national exclusive economic zones. This sector is completely dominated by industrial countries able to afford the new technologies [S 8.6].

The case study on fisheries and tourism from Jamaica and Bonaire (see Box 3.7) demonstrates how natural factors and management decisions influence the development of ecosystem services, a link that has been used extensively by the four scenarios.

Cross-cutting issue 2: Eutrophication

Eutrophication is a major driver of loss of ecosystem services in the marine and coastal zone. A drastic example of the effects of eutrophication on marine and coastal ecosystems is the Gulf of Mexico, where agricultural run-offs created, by 2002, an area of hypoxia of more than 20,000 km^2. (See Box 3.8.)

The hypoxia zone in the Gulf of Mexico would be reduced most in the TechnoGarden scenario, due to improved agricultural practices and better management of the Mississippi river, the Mississippi delta, and New Orleans. The Adapting Mosaic scenario predicts an initial increase in the amount of the dead zone, but due to local efforts the situation would be reversed slowly. Under the Global Orchestration scenario, positive and negative impacts would equal each other, and in effect, the hypoxia zone would increase further. The cumulative effects of the Order from Strength scenario makes it the worst for the future development of the dead zone in the Gulf of Mexico [S 8.7.9]. Table 3.1 summarizes the consequences of each of the four MA scenarios for these main factors. Climate change will not be very different across the scenarios; warming of the Gulf and increased rainfall in the catchment area will worsen the situation in the hypoxia zone.

Box 3.8 CASE STUDY: DEAD ZONES IN THE GULF OF MEXICO

Five factors have been identified that influence the extent of the hypoxia zone in the Gulf of Mexico: climate, agricultural management in the Mississippi catchment area, the management of the Mississippi river, the management of the Mississippi river delta and New Orleans, and fishing practices. These factors largely depend on decisions that have been taken, often decades ago, far away from the Gulf itself. Figure 3.3 shows the direct and indirect drivers of this process.

Figure 3.3 CONCEPTUAL MAP OF DIRECT AND INDIRECT DRIVERS OF THE DEAD ZONE IN THE GULF OF MEXICO

The colours represent different levels of direct and indirect drivers influencing the dead zone [S 8, Figure 8.7].

Cross-cutting Issue 3: Sea-level Rise and Coastal Protection

Climate change is expected to impact (through sea-level rise) severely on coastal wetlands, with substantial losses for estuaries, deltas, and tidal flats as well as accelerating coral bleaching through the increase of sea surface temperatures. This effect is least developed in the TechnoGarden scenario [Wetlands SR 5]. The four scenarios predict a mean global sea-level rise of between 50 cm (TechnoGarden) and 70 cm (Global Orchestration).

The Intergovernmental Panel on Climate Change (IPCC) has described how climate change affects the sea level. Warmer air temperatures result in an expansion of ocean water and a melting of ice from ice caps and glaciers. In addition, stronger winds in the landward direction will also contribute to sea-level rise along the coastline.

Coastal protection as an ecosystem service can be described as the protection of society from storm and related damage through natural buffers such as coral reefs, mangrove forests, and sand bars. The future of this service depends particularly on the degree of sea-level rise and sea surface temperature.

In the Global Orchestration and the Order from Strength scenarios, coastal protection for industrial countries—focused on the repair of damage after it occurrs rather than an active ecosystem management system for prevention—is likely to remain about the same. In developing countries, coastal protection is expected to suffer severely in both these scenarios. Under the Adapting Mosaic and the TechnoGarden scenarios, ecosystem management actively addresses coastal protection, which will generally improve. In developing countries, however, the efforts under the TechnoGarden scenario are frequently hampered by unforeseen responses of ecosystems, and in effect, coastal protection is likely to remain rather unchanged [S 9.5].

Developing countries are likely to be more negatively

impacted by climate change-induced sea-level rise. This is due, amongst other reasons, to sea-level rise requiring new technical solutions such as more efficient dykes and flood gates, which are more affordable in industrial than in developing countries [S 9.5]. Other impacts of global warming on coastal zones are shown in the case study from Papua New Guinea. (See Box 3.9.)

Cross-cutting Issue 4: Biodiversity

Forecasts for biodiversity in marine and coastal ecosystems are severely hampered by the lack of ecological knowledge. Often, even information on the species level is missing. Methodologies such as species-area curves, proven useful for terrestrial ecosystems, do not necessarily work for marine systems for many reasons, including the fact that species extinctions are rarely observed [S 10.4].

The MA has developed the four scenarios in the coastal and marine realm for three different areas, the Gulf of Thailand, the Central North Pacific, and the northern Benguela upwelling ecosystem. For biodiversity, the MA uses an index for biomass that takes the number of species and the number of individuals (biomass) into account. A high value represents a high evenness (even distribution of biomass across a high number of species), a low value the domination of very few species amongst a low number of species [S 10.4.1].

The northern Benguela upwelling current is a highly productive upwelling system off the coast of Southern Africa, with a rich diversity, supporting small, medium, and large pelagic fisheries. The four scenarios all foresee only small changes in the biomass index for the North Benguela, despite differences in emphasis on supporting employment opportunities and ecosystem management.

In the Central North Pacific, fisheries are focusing on tuna. Small tunas have increased in the area with the decline of their large top predators. The TechnoGarden and Global Orchestration scenarios are able to maintain the initial level of biomass diversity, while the Order from Strength scenario predicts an initial decrease, but then a recovery of the biomass index, mainly due to changes in drift net fishing. The Adapting Mosaic scenario allows the index to rise initially due to the closure of turtles fishery and the focus on tuna fishing. With the rebuilding of the most valuable tuna stocks by 2030 increasing the value of fisheries, the overall biomass diversity begins to decrease again. In summary, in the Central North Pacific system, biomass diversity could be increased if the management imperatives for increasing the value of fisheries were substantially reduced [S 10.4].

The most efficient way to rebuild marine biodiversity is an ecosystem-focused policy. Efforts to increase the value of individual stocks and thus increasing their value for fisheries appear to result in a decline of biodiversity. (See Box 3.10 for an example of an ecosystem-based approach in St. Lucia that focuses on marine reserves within a wider zone of fisheries management.)

Box 3.9 CASE STUDY: PREDICTED IMPACTS OF GLOBAL WARMING ON THE COASTAL ZONE OF PAPUA NEW GUINEA [PNG sub-global assessment, 8.2]

The direct impacts of global warming on the coastal zone of Papua New Guinea (PNG) have been assessed in a report covering the whole of the South Pacific region, and may be summarized as follows:

Temperature rise with no decrease in humidity will increase the relative strain index for coastal PNG, with deterioration in human comfort, and increased stress and lower productivity for manual workers. There will be higher demand for building air conditioning, increased energy use, and hence increased cost of work productivity.

Waterborne vector diseases (malaria, dengue fever, filariasis) and skin fungal diseases may have prolonged seasonal virility in coastal areas.

Limestone-based soils are likely to become less fertile as increased temperature changes sodium/calcium ratios.

Ecosystems particularly vulnerable to global warming will be coastal forests, especially mangroves, seagrasses, and coral reefs.

Box 3.10 CASE STUDY: NO-TAKE ZONES IN ST. LUCIA [S 12.4]

The Soufrière Marine Management Area, created in 1995 along 11 km of the coast of St. Lucia in the Caribbean, includes five small marine reserves alternating with areas where fishing is allowed. Roughly 35% of the fishing grounds in this area have been set aside and protected. The initial cost of restricting access to fishers in about a third of the available area (a decline in a provisioning ecosystem service) has been easily compensated for by the benefits. As may be expected, fish biomass inside the reserves tripled in just four years, but, more importantly, biomass in the fished areas doubled during the same period, and remained stable thereafter. In less than the typical term of an elected governmental official, the fishery recovered and landings increased. There is growing evidence from around the world supporting marine reserves and fishery closures as an effective tool for managing fish, one of the most important provisioning ecosystem services. Wise local management of fisheries averted a negative impact, possibly for the long term.

4 *What can be done about the loss of marine and coastal ecosystems and their services?*

- The MA explores a wide range of responses to the human impact on ecosystems. Operational responses are important to consider for all policy options, whereas specific responses relate to sectors.
- The *operational response options* include the following:
  stakeholder participation in decision-making from global to local levels;
  development of stakeholder capacity;
  communication, education, and public awareness, and the empowerment of communities;
  generating alternative incomes;
  monitoring of biophysical and socioeconomic effects of responses,
  addressing of uncertainties, such as basic knowledge of biodiversity and ecosystem processes; and
  addressing trade-offs among uses of ecosystem services.
- The *specific response options* include the following:
  international and regional mechanism that may focus on biodiversity, fisheries, habitat loss, or wider aspects of sustainable development;
  successful implementation of international agreements;
  integrated coastal management requiring a holistic view including land-based and freshwater influences;
  marine protected areas;
  coastal protection against storms and floods through provision of natural barriers;
  management of nutrient pollution and waste at source point;
  geo-engineering for CO sequestration;
  economic interventions such as financial incentives, taxes, and subsidies;
  fisheries management; and
  aquaculture management.
- Important tools for applying policy options include multicriteria analysis, scenarios, environmental impact assessment, and economic valuation.
- Effort needs to be made in the implementation and enforcement of existing legislation and policy.

Introduction

People have been influencing ecosystems as long as humankind has existed, and there has always been a challenge to address human impacts on the ecosystems and the services they provide. The recent dramatic scale of harmful impacts, however, many of them visible beyond local, national or regional boundaries, underlines the need for increasing the regulation of human activities, with a need to choose the appropriate response level—local, national, regional or global. It is essential however, that existing relevant policies and legislation are also implemented and enforced. This chapter examines the main responses that societies have recently applied for regulating their interaction with coastal and marine ecosystems. A distinction is made between operational and specific responses, with the former not being bound to specific sectors but being important to consider for all policy options. The responses are outlined below, indicating their effectiveness, the type of responses, and the required actors.

Response Options

In the following paragraphs, a response is considered to be effective when its assessment indicates that it has enhanced the particular ecosystem service and contributed to human well-being without significant harm to other ecosystem services or harmful impacts to other groups of people. A response is considered promising either if it does not have a long track record to assess but appears likely to succeed or if there are known means of modifying the response so that it can become effective. A response is considered problematic if its historical use indicates either that it has not met the goals related to service enhancement (or conservation and sustainable use of biodiversity) or that it has caused significant harm to other ecosystem services. Labelling a response as effective does not mean that the historical assessment has not identified problems or harmful trade-offs. Such trade-offs almost always exist, but they are not considered significant enough as to negate the effectiveness of the response. Similarly, labelling a response as problematic does not mean that there are no promising opportunities to reform the response in a way that can meet its policy goals without undue harm to ecosystem services.

The typology of responses presented in the following paragraphs is defined by the nature of the intervention, classified as follows: institutional and legal (I), economic and incentives (E), social and behavioural (S), technological (T), and knowledge and cognitive (K). Note that the dominant class is presented. The actors who make decisions to implement a response are governments (G) at different levels, such as international (GI) (mainly through multilateral agreements or international conventions), national (GN), and local (GL); the business/industry sector (B); and civil society, which includes nongovernmental organizations (NGO), community-based and indigenous people's organizations (C), and research institutions (R). The actors are not necessarily equally important [General SR, Appendix B].

Operational Responses

Stakeholder Participation in Decision-making

Effectiveness: Effective
Type of response: Institutional and legal (I), social and behavioural (S)
Required actors: National government (GN), local government

Box 4.1 LARGE MARINE ECOSYSTEMS [CT 19.5.2]

Regional agreements are thought to be a more effective way to manage shared coastal and marine resources, especially when such agreements capitalize on better understandings of costs and benefits accruing from shared responsibilities in conserving the marine environment. Large marine ecosystems (LMEs) have been put forward as a logical way to frame area-based approaches of many agreements and mechanisms. The world's seas have been divided into 64 LMEs, with each LME covering an area of around 200,000 km^2 and characterized by specific bathymetry, hydrology, productivity, and trophically dependent populations.

Using an LME framework ensures a holistic approach by facilitating a process where issues both environmental and sociopolitical are first considered at a regional level through the creation of an action plan and then addressed again through a series of national planning exercises. Such planning can take into consideration many of the different response options available to decision-makers.

Several recent international instruments refer to LMEs, and the geographic units serve as the basis for some global assessments, such as UNEP's Global International Waters Assessment (GIWA). In many parts of the world, however, the political constituency for nations to cooperate to conserve large-scale ecosystems is lacking, though this situation may well be improving.

(GL), nongovernmental organization (NGO), business/industry (B), community groups (C), research institutions (R)

Stakeholders include government bodies, local and indigenous communities, nongovernmental organizations as well as the private sector, the latter particularly in the case of industrial fisheries [CT 18.9]. Local-level involvement has in many cases proven to improve the recovery of coastal ecosystems. Local or indigenous perspectives might provide for alternative management priorities [R 3.5]. Key steps to improve participatory processes are to increase the transparency of information, improve the understanding of the issues, improve the representation of marginalized stakeholders, engage them in the establishment of policy objectives and priorities for the allocation of services, and create space for deliberation and learning accommodating multiple perspectives [R 7]. The case studies on the Mankote Mangrove in St. Lucia (Box 4.2) and the village fish reserves in Samoa (Box 4.7) provide examples of successful stakeholder participation.

Capacity Development

Effectiveness: Effective
Type of response: Institutional and legal (I)
Required actors: National government (GN), local government (GL), nongovernmental organizations (NGO), community groups (C), research institutions (R)

Box 4.2 CASE STUDY: THE MANKOTE MANGROVE IN ST. LUCIA [R 17, Box 17.2]

The Mankote Mangrove constitutes 20% of the total mangrove area in St. Lucia. Uncontrolled charcoal harvesting through excessive tree loggings created a severe environmental decline of the mangroves, which posed a serious threat to many of the ecosystem services that the mangrove provided, including water quality, coastal stability, bird habitat, and fish breeding. Local communities, consisting primarily of poor people, undertook the practice of harvesting charcoal. These communities had no legal right to use the publicly owned mangrove resources. With no possibility for substitution, the loss of access to the mangroves by these poor populations due to resource depletion or degradation would have created permanent loss of their only source of income.

To address this problem, the following solution was implemented:

- The local communities were organized into informal cooperatives and given communal legal and exclusive rights to harvest the charcoal.
- They were involved in monitoring the programme, to get accurate information on the overall health of the mangrove.
- Measures to increase the supply of wood outside the mangrove reserve were put in place, as were alternative job options for charcoal harvesters, including in tourism.

The effort yielded the following results:

- The decline in the Mankote Mangrove was halted and reversed.
- The density and size of trees increased.
- Charcoal harvests were maintained.
- The range of employment options for the poor population somewhat increased.

This is a clear case where a property and legal rights approach made sense, because the subsistence harvesters were the primary source of the problem due to uncontrolled harvesting of charcoal. The use of formal rights to the resource gave the poor an incentive for long-term management of the mangrove as an asset over which they had control. The introduction of a monitoring programme further improved the level of and access to information they had about the general condition of the mangrove.

Management of marine and coastal ecosystems and the associated impacts on human well-being is often inadequate, leading to conflicts and a decrease in services. A particular challenge is provided by the need to take into account the impacts of external influences on the marine and coastal systems, such as climate change or land-based pollution and degradation [CT 19.1]. A crucial component of such an approach is the development of capacity.

Communication, Education, and Public Awareness

Effectiveness: Effective
Type of response: Social and behavioural (S)
Required actors: National government (GN), local government (GL), nongovernmental organizations (NGO), community groups (C)

Communication, education, and public awareness are important components of successful ecosystem management, ensuring that decision-makers, managers, and other actors fully understand the background to and implications of their activities. Communication, education, and public awareness bear particularly good results when accompanied by efforts to empower communities to take decisions on the management of ecosystems [R 5.2.9]. Providing the human and financial resources to undertake effective work in this area is a continuing barrier [R 5]. The Mankote mangrove in St. Lucia provides an example of the successful use of communication and public awareness raising in a coastal context. (See Box 4.2.)

Alternative Income-generating Activities

Effectiveness: Promising, problematic
Type of response: Economic and incentives (E), social and behavioural (S)
Required actors: Local government (GL), nongovernmental organizations (NGO), community groups (C)

It is increasingly recognized that some human activities are no longer appropriate or sustainable in marine and coastal ecosystems and alternative forms of income generation (AIGAs) are needed for those users who will be directly affected. Developing AIGAs requires a long-term commitment from all actors and considerable effort to build capacity, change attitudes, provide a social net and financial resources to ensure that users do not return to their former livelihoods. The case study on the Mankote mangrove in St. Lucia (Box 4.2) illustrates an example of alternative income-generation.

Monitoring

Effectiveness: Effective, promising
Type of response: Institutional and legal (I), technological (T), knowledge and cognitive (K)
Required actors: Government at an international level (GI), national government (GN), local government (GL), nongovernmental organizations (NGO), community groups (C), research institutions (R)

Monitoring is a crucial component of any management strategy. It is best used by applying indicators. Given the substantial deficiencies in understanding marine and coastal ecosystems, the development of indicators for biophysical and socioeconomic responses to management measures is currently limited. Indicators for institutional and governance responses are available to an even lesser degree [Wetlands SR 6.3; R 18.3]. The involvement of the community in the monitoring of ecosystems is key to the success. Monitoring plays an important role in the Mankote mangroves in St. Lucia. (See Box 4.2.)

Addressing Uncertainty

Effectiveness: Promising, problematic
Type of response: Institutional and legal (I), knowledge and cognitive (K)
Required actors: National government (GN), local government (GL), community groups (C), research institutions (R)

To a larger degree than terrestrial ecosystems, marine systems confront decision-makers, ecosystem managers, and researchers with a high degree of uncertainty. Uncertainty results from a lack of understanding of coastal and marine ecosystems [CT 4; S 3.4.6: S 4.8; R 6.2.3], particularly about:

- knowledge of deep-sea biodiversity, including taxonomy and ecosystem composition;
- patterns of endemism;
- habitat data such as long-term and large-area ecological processes;
- understanding of the oceanic nitrogen cycle; and
- population dynamics and related recovery potential of commercially exploited resources.

A precautionary approach, taking these uncertainties into account, is needed for policy responses in the coastal and marine realm.

Trade-off Analysis

Effectiveness: Promising, problematic
Type of response: Institutional and legal (I), economic and incentives (E)
Required actors: National government (GN), local government (GL), community groups (C)

Trade-offs between ecosystem services will be essential in the future to make equitable and sustainable use of the world's resources. Policy decisions will need to address trade-offs between activities that impact coastal and marine well-being and land uses such as fisheries, agricultural production, water quality, and upstream barriers to water flow to coastal zones. The lack of understanding of ecosystem services, including their economic values, contributes to difficulties in finding the right balance [CT 19.5.1]. Tools for addressing trade-offs include, for example, environmental impact assessment (see page 53) and the zoning of areas, which has been applied in many terrestrial areas, but less so in marine and coastal systems.

Specific Responses

Applying International/Regional Mechanisms

Effectiveness: Promising, problematic
Type of response: Institutional and legal (I)
Required actors: Government at an international level (GI), national government (GN)

There is a multitude of global and regional agreements, instruments, and programmes facilitating international cooperation concerning the conservation and sustainable use of marine and coastal ecosystems [C18, 19; R5, 15]. (For a list of agreements see Appendix 1; for two examples, see Box 4.3). Their effectiveness is dependent on government commitment to build the capacity to implement and enforce compliance of the provisions of the instrument [C18, 19; R5, 15]. (See Box 4.4.) This includes the availability/provision of human and financial resources. Better coordination among conventions across national jurisdictions and on the high seas would increase their usefulness. Attention is needed on integrating these instruments into national and local institutions. Local stakeholders can take advantage of international instruments to gain wider exposure for their issues and concerns. (For a case study on the governance challenge for the Caribbean region, see Box 4.5.)

Box 4.3 EFFECTIVENESS OF INTERNATIONAL INSTRUMENTS

An analysis of the compliance by 11 European and North American countries with treaties and conventions that apply to North Atlantic Fisheries found that compliance has very little to do with sustainable fisheries management [C 18.6]. Many of the stocks such as tuna, cod, and herring managed by the various instruments are overexploited, threatened, or collapsed.

Instrument (see Appendix 1 for full titles)	Average Compliance Score (%)
UNCLOS	79
Fish Stocks	47
Compliance	33
NAFO	68
NEAFC	81
ICCAT	54
ICES	52
CFP	49
Coop Agreement	41
NSS herring	78
Capelin	71

Box 4.4 EXAMPLES OF KEY INTERNATIONAL INSTRUMENTS

United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS) regulates all aspects of the resources of the sea and the uses of the ocean, such as navigational rights, territorial sea limits, economic jurisdiction, legal status of resources on the seabed beyond the limits of national jurisdiction, passage of ships through narrow straits, conservation and management of living marine resources, protection of the marine environment, a marine research regime, and (a more unique feature) a binding procedure for settlement of disputes between States.

UNCLOS gives national sovereignty to nations over their marine resources within 200 nautical miles of their coasts, while outside of the 200 mile limit, conservation and management of marine resources becomes a collaborative effort between nations accessing those resources. UNCLOS provides the framework to develop agreements such as the Straddling Stocks and Compliance Agreements to deal with high seas issues.

The FAO Code of Conduct for Responsible Fisheries

The code includes technical guidelines as well as recommendations to:

- apply an ecosystem approach to fisheries;
- manage stocks using the best available science;
- apply the precautionary principle, using conservative management approaches when the effects of fishing practices are uncertain;
- avoid overfishing and prevent or eliminate excess fishing capacity;
- minimize waste (discards) and bycatch;
- prohibit destructive fishing methods;
- restore depleted fish stocks;
- implement appropriate national laws, management plans, and means of enforcement;
- monitor the effects of fishing on all species in the ecosystem, not just the target fish stock;
- work cooperatively with other states to coordinate management policies and enforcement actions;
- recognize the importance of artisanal and small-scale fisheries and the value of traditional management practices; and
- integrate fishery management into coastal area management.

Article 9 of the FAO Code of Conduct for Responsible Fisheries sets principles and guidelines for the sustainable development and management of aquaculture.

The Code of Conduct is a voluntary instrument and its effectiveness depends on the willingness of countries to implement it.

Box 4.5 CASE STUDY: CHALLENGES FOR POLICY RESPONSES IN THE CARIBBEAN

The Caribbean Sea comprises territorial waters and coastal areas of 33 bordering countries and territories, which makes a coordinated approach to management of the area extremely difficult. Players are not only those countries and territories, but also the colonial powers from North America and Europe; international institutions such as UNEP, UNDP, World Bank, and the Organization of American States; international NGOs; the Western Central Atlantic Fisheries Commission of the FAO (WECAFC); donor agencies; and regional intergovernmental organizations such as the Association of Caribbean States (ACS) and the Caribbean Community (CARICOM).

The scale of problems such as overfishing, pollution, and expanding tourism is not matched by an appropriate managerial response, as management is organized along the lines of individual countries or political blocks such as CARICOM.

The existing governance framework makes for much complexity, presenting many challenges such as the lack of harmonization. This extends into the nongovernmental sector where NGOs are not well integrated into the policy analysis and decision-making process. On the other hand, the diversity of the governance structure offers a variety of opportunities for exercise of authority in relation to shared issues and interests. However, it has been suggested to create another decision-making body at the highest regional intergovernmental level.

Globally, the United Nations has recently addressed attention to the Caribbean Sea, stressing, in UN Resolution 57/216, the need for a comprehensive and integrated approach to the management of the Caribbean Sea. This Resolution offers a high-level and up-to-date common policy basis upon which wider Caribbean states might take concerted action among themselves and upon which they might enlist global cooperation in an effort to meet the objectives of the policy.

Source: Caribbean Sea sub-global assessment, 1.3 and 6.2.

Linking the Integrated Management and Planning of River Catchments and Coastal Areas (integrated coastal management and planning)

Effectiveness: Effective, promising
Type of response: Institutional and legal (I), social and behavioural (S)
Required actors: National government (GN), local government (GL), community groups (C), research institutions (R)

An integrated approach to coastal management requires a holistic view that includes land-based and freshwater influences, and the necessary political, economic, and social conditions [CT 19.5.2]. Land use planning and inshore resource management—including zoning, catchment management, and impact assessments—are linked to integrated coastal zone management (ICZM) horizontally (across sectors) and vertically (across levels of government) [R 15.5.3]. This approach to management and planning provides a balance among the users and ecosystem needs which is often found by exploring the trade-offs that are needed.

ICZM deals with the drivers of coastal change through three major ways [R 15.5.3]:

- addressing conflicts between uses and users of natural resources;
- regulating increasing demands on coastal resources by improving management and planning processes; and
- promoting institutional changes relating to decision-making about coastal zones through more inclusive decision-making, capacity-building, and inter-agency coordination.

The case of coastal planning in British Columbia (see Box 4.6) provides an example of how a participatory process supports integrated coastal management.

Marine Protected Areas

Effectiveness: Effective, promising
Type of response: Institutional and legal (I), social and behavioural (S)
Required actors: National government (GN), local government (GL), nongovernmental organizations (NGO), community groups (C)

Marine protected areas (MPAs) can be defined as areas of the ocean designated to enhance conservation of marine resources; marine reserves are those protected areas of the ocean that are completely protected from all extractive and destructive activities [R 5.2.6]. MPAs are important in conserving biodiversity and managing marine and coastal ecosystems, as well as in contributing to the sustainable use of marine resources. MPAs that exclude extractive activities (marine reserves) tend to lead to increases in the density, biomass, individual size, and diversity of vertebrate species, thus conserving biodiversity and reducing the risk of extinction for some marine species. Networks of reserves are necessary for long-term fishery and conservation benefits; and increased reserve size, up to an optimal maximum depending on objectives, tends to lead to increased benefits, but even small reserves often have positive effects. Some coastal areas under some form of community management can yield better results for biodiversity and human well-being than officially recognized areas [CT 19.5.2]. Box 4.7 provides examples of successful marine protected areas in the Bahamas and Samoa. Notwithstanding their potential benefits, marine protected areas need to be properly designed and managed in order to achieve their objectives. Enforcement of MPAs can be problematic and to be effective they must enjoy the full support of all stakeholders.

Box 4.6 CASE STUDY: PARTICIPATORY LAND USE PLANNING IN COASTAL BRITISH COLUMBIA, CANADA

In coastal British Columbia, the economy strongly depends on natural resources. Uncertainties about land resource use issues led the Provincial Government to initiate a major planning process for the central and north coasts and the Haida Gwaii/Queen Charlotte Island area. Its purpose was to enable all parties—the Provincial Government, First Nations, local governments and communities, the forestry, fishing, tourism, and mining sectors, environmental groups, and others—to reach agreement on the future development and conservation of land resources. In 2001, this process established:

- a government-to-government relationship between the Province and the First Nations,
- a commitment of all land-use planning to promote ecosystem-based management,
- the Coast Information Team (CIT), an independent body providing the best available information and expertise for ecosystem-based development.

The CIT consisted of scientists, practitioners, and traditional and local experts, overseen by a Management Committee and supported by a secretariat.

The CIT was tasked to produce information to support governments and participants in the planning processes reach decisions that achieved ecosystem-based management, and specifically to provide:

- an ecosystem-based management framework;
- regional and subregional analyses;
- a hydro-riparian decision tool;
- technical support for pilot projects investigating local applications of ecosystem-based management;
- additional information to assist Land and Resource Management Plans and First Nations' Land Use Plans.

Source: Coastal British Columbia sub-global assessment, 1.3–1.5.

Box 4.7 BENEFITS FROM MARINE PROTECTED AREAS: BAHAMAS AND SAMOA [R 5, Box 5.1]

Bahamas

The Exuma Cays Land and Sea Park (45,620 ha) was established in 1958 covering both the terrestrial and marine environments associated with these islands. The Park became a no-take fisheries reserve in 1986. Research has shown that the concentration of conch in the park is 31 times greater than outside the park, providing several million conchs per year to areas outside the park available to be harvested by fishers. Additionally, tagged grouper from the Exuma Park have been caught off both north and south Long Island (Bahamas), indicating the Park is replenishing grouper stocks in areas as far as 250 km away. Tagged spiny lobsters from the Exuma Park are found replenishing the marine environment of Cat Island, 100 km away. The success of fisheries resource replenishment in the Exuma Park led the government to announce a policy decision in 2000 to protect 20% of the Bahamian marine ecosystem, doubling the size of the national protected areas system.

Samoa

In the Pacific Island of Samoa, as in many countries in the tropics, catches of seafood from coastal areas, lagoons, and inshore reefs have been decreasing over the past 10 years. Reasons for this decline include overexploitation, the use of destructive fishing methods (including explosives, chemicals, and traditional plant-derived poisons), and environmental disturbances. In order to address this problem, the Samoan Fisheries Division initiated in 1995 a community-based extension project in 65 villages which recognized the village fono (council) as the prime agency responsible for actions. A large number of villages (38) chose to establish small village fish reserves in part of their traditional fishing areas and decided to actively support and enforce government laws banning the use of explosives and chemicals for fishing. Some villages also set minimum size limits for capturing fishes. While many of the village reserves are small (ranging from 5,000 to 175,000 m^2), their number and the small distance among them forms a network of fish refuges. In just a few years, fisheries stocks have increased 30–40% and there are signs of recovery in reefs previously affected by destructive fishing methods. As the fish reserves are being managed by communities which have direct interest in their success, prospects for long-term sustainability of this initiative are high.

Marine protected areas and reserves are one tool of several for fisheries management, and an adaptive approach, allowing for assessment and modification as new information and challenges arise, is required [CT 18.7.4].

The benefits of marine protected areas for adjacent areas and fisheries are difficult to assess, due to problems in measuring those impacts and the fact that few marine protected areas have been in existence long enough [R 5.2.6; 6.3.6]. However, it has been demonstrated for some cases that fish larvae or adults, migrating outside of the reserve, increase the yields for fishermen in surrounding areas [R 6.3.6]. Despite the uncertainties over these impacts, marine protected areas and reserves, and particularly networks of such areas, if managed well, are most likely to become a very important tool in the management of many fisheries and the sustainable use of ecosystems, adding value to other approaches [R 6.3.6]. Methods for design and location need further development.

Coastal Protection

Effectiveness: Effective, promising, problematic
Type of response: Technology (T)
Required actors: Government at an international level (GI), national government (GN), business/industry sector (B)

Land use planning and habitat conservation that protect natural barriers such as mangroves and intertidal flats are soft or nonstructural measures for coastal protection. Soft measures are more flexible, cost-effective, and sustainable, particularly in the light of climate change-induced increases in flood and storm events. Expensive hard or structural measures such as embankments and dykes remain necessary in certain cases. The restoration of lost or damaged ecosystems remains a major—and expensive—challenge for coastal protection, facing the difficulty of anticipating future disturbances [R 11.1; R 11.3; R 17.2.4]. A number of examples of the use of land use planning for coastal protection are provided in Box 4.8.

Management of Nutrient Pollution: Runoff and Fossil Fuel Combustion

Effectiveness: Effective, problematic
Type of response: Institutional and legal (I), technological (T)
Required actors: Government at an international level (GI), national government (GN), local government (GL)

Box 4.8 EXAMPLES OF LAND USE PLANNING FOR COASTAL PROTECTION [R 11, Box 11.2]

Florida

The Standard Building Code (SBC) or the National Flood Insurance Program (NFIP) governs construction along or near the Florida coastline. Compliance with these codes makes individuals and businesses within the communities eligible to purchase flood insurance. In the 1980s, Florida reinforced the stipulations contained in the SBC and the NFIP by establishing the Coastal Construction Control Lines (CCCL), which defines specific areas along the coastline that are subject to flooding and erosion. The CCCL was adopted throughout Florida between 1982 and 1991 and reflects storm impact zones over a 100-year period. Distinctions were made between two categories of structures based on the CCCL regulations: (1) structures located seaward of the CCCL that were built prior to enactment of the CCCL regulation were categorized as non-permitted structures at risk of sustaining hurricane damage; and (2) structures built after the adoption of the CCCL require a special building permit to certify that the builder will adhere to a more rigid set of building standards designed to reduce the risk of structural damage that can be sustained during a hurricane.

Canada

New Brunswick completed remapping of the entire coast of the province to delineate the landward limit of coastal features. The setback for new development is defined from this limit. Some other provinces have adopted a variety of setback policies, based on estimates of future coastal retreat.

Barbados

A national statute establishes a minimum building setback along sandy coasts of 30 m from the mean high-water mark; along coastal cliffs the setback is 10 m from the undercut portion of the cliff.

Aruba and Antigua

The setback is established at 50 m inland from high-water mark.

Sri Lanka

Setback areas and no-build zones are identified in a Coastal Zone Management Plan. Minimum setbacks of 60 m from mean sea level are regarded as good planning practice.

United Kingdom

In 1998, the House of Commons endorsed the concept of managed realignment as the preferred long-term strategy for coastal defence in some areas.

United States

The states of Maine, Massachusetts, Rhode Island, and South Carolina have implemented various forms of rolling easement policies to ensure that wetlands and beaches can migrate inland as sea-level rises.

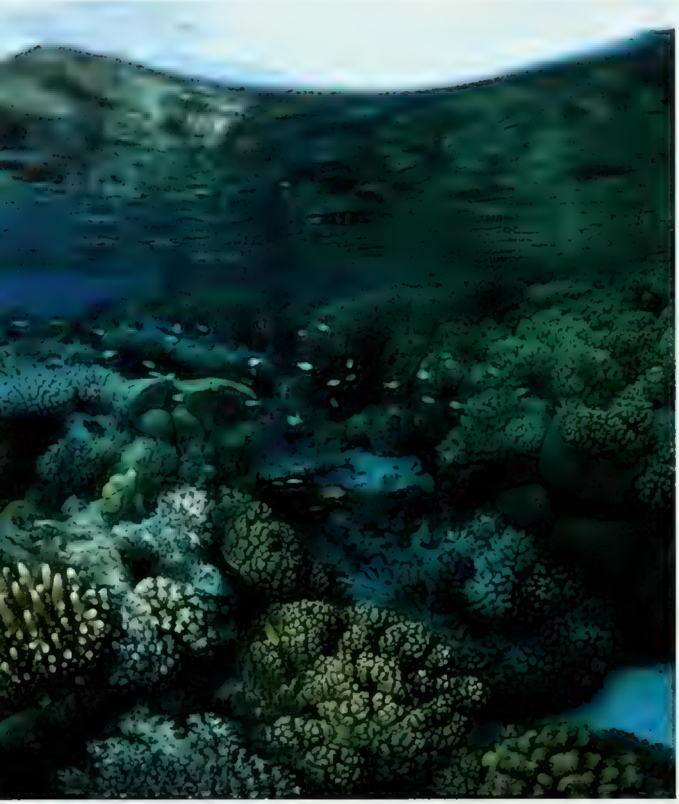
Australia

Several states have coastal setback and minimum elevation policies, including those to accommodate potential sea-level rise and storm surge. In South Australia, setbacks take into account the 100-year erosional trend plus the effect of a 0.3 m sea-level rise to 2050. Building sites should be above storm surge flood level for the 100-year return interval.

A number of methodologies to reduce the nitrogen pollution of coastal waters have been elaborated [R 9.5.1; R 9.5.5; R 9.5.6]. Coastal nutrient pollution should be addressed at its sources, including runoff and leaching from agricultural fields, concentrated animal feeding operations, fossil fuel combustion, and urban sources. Watershed, river basin, and national, if not international, levels are most suitable to take effective action to reduce the nitrogen (N) input into coastal waters. Wetlands acting as sinks of both nitrogen and phosphate can help enormously in reducing coastal water pollution; hence wetland conservation and restoration need to be taken more seriously. A related option is to allow for higher N-load limits for N-insensitive ecosystems and lower N-load limits for ecosystems that are highly N-sensitive. Alternatively, specific N-input levels could be set up for individual coastal rivers and bays. Site-specific approaches add significantly to general N-input reductions as they take the sensitivities of individual sites into account.

Waste Management: Household and Industrial Sewage

Effectiveness: Effective, problematic
Type of response: Institutional and legal (I), economic and incentives (E), social and behavioural (S), technological (T)



Required actors: Government at an international level (GI), national government (GN), local government (GL)

Control of waste pollution of oceans and coastal waters has become a major instrument in managing marine and coastal ecosystems, particularly in developed countries that have the resources and abilities needed. Instruments to address waste pollution of coastal and marine ecosystems range from a change in production and consumption patterns, the strengthening of reuse and recycling systems, and improved waste management facilities to the use of wetlands for managing sewage sludge and waste water as well as dumping at sea and ballast water management. Issues of governance structures, institutional arrangements, civil society involvement, and poverty would need to be integrated into waste management strategies [R 10.3; R 10.4; R 10.6]. Pollution by waste in the high seas has become an even more challenging issue with the discovery of biodiversity-rich and complex ecosystems such as deep-sea vents.

Geo-engineering: Carbon Dioxide Sequestration

Effectiveness: Problematic
Type of response: Institutional and legal (I), technological (T)
Required actors: Government at an international level (GI), national government (GN), business/industry sector (B)

For mitigation of climate change, increasing the biological sequestration of carbon dioxide in the oceans has been proposed [C18]. Currently, the effects of such measures are hard to predict on a larger scale. The main methodology would be the fertilization of low productivity marine waters with iron. That would stimulate the growth of phytoplankton that in turn would fix larger amounts of carbon dioxide. Experiments with this approach have demonstrated significant changes in the biological community composition but the medium to long-term impacts are unknown. There is also a risk of algae outbursts leading to anoxia and the large-scale production of methane, a powerful greenhouse gas [CT 18.8.4; R 13.5.4].

Economic Interventions: Market-based Instruments

Effectiveness: Promising, problematic
Type of response: Economic and incentives (E)
Required actors: National government (GN), business/industry sector (B)

Economic interventions (market-based instrument) such as subsidies, taxes, and financial incentives have a long history with respect to the marine ecosystems, with consequences varying with countries and the application of the instrument. Some incentives—including subsidies for fisheries and coastal development—have had unwanted side effects, while others have reduced the impacts of fishing or coastal development [CT 18.5.2]. Incentives might be provided in the form of fees for the right to fish or for nonexploitative fishing alternatives such as sports fishing and tour guiding; fiscal expenditure on retraining of fishers; and incentives for investment in alternative economic activity in fishing communities such as small-scale tourism. Perverse incentives in fisheries continue to be inadequately addressed. They refer to, for example, size limits for landed fish, encouraging undersized bycatch to be discarded at sea, and decommissioning schemes that result in fleet modernization [CT 18.4]. It remains a major challenge for marine and coastal management to introduce payments for ecosystem services such as coastal protection. So far these services are undervalued [Wetlands SR 6.4].

Fisheries Management

Effectiveness: Promising, problematic
Type of response: Institutional and legal (I)
Required actors: National government (GN), local government (GL), business/industry sector (B), community groups (C)

Fisheries management options range from strict enforcement of regulations that include the establishment and implementation of quotas, gear restrictions and spatial closures, programmes to address unreported and unregulated catches, and decommissioning schemes. MPAs can help to enhance fisheries

Table [illegible] MAIN POLICIES FOR THE MANAGEMENT OF OPEN-ACCESS FISHERIES [Based on R 6, Table 6.3]

[illegible]	
Fishing effort regulation	In this policy, one of the inputs in the index for fishing effort is restricted (for example, number of days at sea). Effort regulation is usually used with other regulations to ensure that the negative impacts of reduced effort (e.g. increased gear efficiency) are minimized. Regulations are most effective when there are enforcement programmes in place and the consequences of breaking the regulations act as a deterrent.
Decommissioning schemes	The purpose of this policy is to bring the capacity in line with catch potentials. This is done by reducing the fleet capacity through subsidized buy backs. This option needs to be carefully considered so that the overall fishing capacity of the fleet is reduced and not redistributed.
Total quotas or Total allowable catches (TACs)	In this policy, a total quota is imposed on the fishery and when this quota has been filled, the fishery is closed. The total quota is often recommended to be set at a level where catches can be sustained. Total quotas have in some cases been used in conjunction with individual quotas (IQs), for example, in the case of Iceland and New Zealand.
Rations	Under a rations policy, the total quota is distributed in short time intervals on vessels, reflecting seasonal variations in catch possibilities. Rations are used for some species in Denmark. However, the system of rations creates huge information requirements.
Licence systems	A licence system normally specifies who can enter the fishery, how much can be caught and the weight of this catch. The purpose is to control the catch of each individual vessel. This policy response can have negative consequences if practices such as high-grading are not managed.
Individual quotas (IQs)	This policy sets a nontransferable individual annual quota that cannot be changed during the year and may, therefore, be thought of as a property right. Indeed property rights regulation is very popular within fisheries; property rights regulate more than 55 fisheries in the world.
Individual transferable quotas (ITQs)	Under this policy, the individual quotas (IQs) are made transferable between fishermen. ITQs are used in, for example, Iceland, the Netherlands, and New Zealand. ITQs generally benefit the fisheries, but the economic and social consequences to some fishers can be negative for some fisheries.
Taxes or landing fees	In this policy either fishing effort or catch is used to compile the tax. In practice taxes are not popular among fishermen and there are severe implementation problems.
Bilateral agreements	Agreements where one country allows foreign fishing vessels into its EEZ can generate economic and social benefits to the country with minimal impact on marine ecosystem services. The effectiveness of these agreements in delivering the potential benefits is high in developed countries, and much more variable in developing countries. The provisions that are negotiated need to be carefully considered and resources allocated to enforce the terms of the agreement by the parties.

Box 4.9 CASE STUDY: NATIONAL FISHERIES SECTOR IN CHILE [R 17, Box 17.3]

In the fisheries sector in Chile, fish stocks started depleting greatly after the industry was privatized in 1973. Particularly affected were artisanal fisherman who, under the individual transferable quota (ITQ) system, cannot compete with industrial fisheries in the market and lose their livelihoods. To address this issue, individual transferable quotes were implemented for separate subclasses of fisheries and limited to industrial/commercial fishers.

The success of the programme is unclear. As structured, the ITQs policy has protected industrial-country fishing interests, but reduced the potential benefits of the market-based quotas. The issue of artisanal fishermen has not been properly addressed, and regular updating of information about fishery health remains a problem. The small percentage of total catch currently covered suggests that ITQs are not yet addressing the higher goal of protecting Chilean fisheries.

The rationale for using these measures was two-fold: to apply regulatory efforts more consistently and to control access rights.

management measures. The FAO Code of Conduct for Responsible Fisheries provides voluntary guidelines for managing fisheries. (See Box 4.3.) Implementation of the Code could be strengthened by national implementation plans [R 6.3.6]. Increasingly, an ecosystem-based approach to fisheries management is being emphasized. (See Box 4.9 for a case study of the national fisheries sector in Chile.) Which policies to apply depends on the social and institutional context of particular fisheries. (See Table 4.1 for a summary of the main policies available to manage open-access fisheries.)

Aquaculture Management

Effectiveness: Promising, problematic
Type of response: Institutional and legal (I)
Required actors: National government (GN), local government (GL), business/industry sector (B), community groups (C)

The impact of aquaculture in contributing to the Millennium Development Goal of eradicating extreme poverty and hunger (MDG 1) on other ecosystem services can be managed if the establishment of aquaculture facilities (land-based or offshore) is done in the context of integrated coastal management and broad fisheries management policies and the operation of these facilities is in line with the FAO Code of Conduct for Responsible Fisheries, which provides principles and guidelines for the sustainable development and management of aquaculture.

Genetically modified fish raise environmental concerns, such as risks of genetic pollution or outcompeting of wild stocks, and need to be addressed through strict controls, including the application of sterile animal techniques that prevent reproduction of genetically modified fish [R 6.3.4; R 6.3.6].

Other Response Options

New response options are being continually developed; while some are still untested, they may prove to be powerful mechanisms in the future. Future response options may include integrated ocean management, ocean zoning, and a range of ocean policies.

Evaluating Policy Responses

Responses need to take into account the trade-offs and the uncertainties. They also need to address the interests of stakeholders, with a view to support vulnerable and weak stakeholders who are often found in the communities most affected by environmental change. The following guidelines could support the evaluation and selection of appropriate response options [R, Table 18.1]:

- Use the best available information about the social, economic, political, technological, and institutional context.
- Use the best available ecosystem/biophysical information.
- Consider concerns and implications regarding procedural and outcome efficiency.
- Strive for effective procedures and results.
- Consider equity concerns and implications, including for stakeholder participation and a transparent outcome; strive for consensus among stakeholders.
- Use the best available information about values, beliefs, and aspirations of stakeholders.
- Pursue accountability through clear responsibility assignments during and after the decision process.
- Consider concerns and implications for vulnerable groups/communities.
- Consider uncertainties, allowing for policy corrections as new

information becomes available or values or positions of stakeholders change.

- Consider cross-scale effects, allowing for incorporation of constraints from higher decision-making levels and for exploring decision needs at lower decision-making level.
- Take an adaptive approach that incorporates mechanisms to monitor and review the effectiveness and to make changes to the process in a timely and responsive manner.

Tools for Policy Options

Multicriteria analysis (MCA) is a decision support tool guiding stakeholders in considering the merits of different management strategies and in determining management priorities. It enables decision-makers to assess the relative merits of various policy options by using mathematical programming techniques to select options based on objective functions with explicit weights that stakeholders apply. MCA can reflect multiple goals or objectives for the resources; however, it has large data needs and can use unrealistic characterization of decision-making. It has been used to explore regional trade-offs in the design of protected areas systems [R 5.2.4; R 15].

Scenarios are storylines that may or may not be harmonized with quantitative modelling. They show plausible futures, which can be used to explore the consequences of specific policy directions; they are not projections or predictions of what will happen. The storylines are often developed through consensus of experts as to how ecological, economic, and social systems will react under a given set of drivers that are based on distinct conditions. When quantitative models are used to model the storylines, scenarios can be powerful tools to explore the consequences of major policy shifts that might be considered by decision-makers. Scenarios were used extensively in the MA, and Box 4.10 illustrates how they were used to explore the development of biodiversity in the Gulf of Thailand under the four scenarios [S 8, 9, and 10].

Environmental impact assessment (EIA) is a tool used by countries and financial and lending institutions such as the World Bank and the regional development banks to assess management interventions. It is a structured process that enables managers and decision-makers to evaluate the ecological, social, and economic impact of policy decisions [R 15].

Economic valuation refers to the net benefits of one policy response over another; it is often used to evaluate which option is the preferred one. They are often used in trade-off analyses. The market and nonmarket value of the ecosystem services should be used in valuation studies where possible. Cost information and direct value information is often available, but information on benefits or nonmonetary values is usually limited. The case study from Thailand (Box 4.11) is an example of the use of economic valuation studies.

Box 4.10 BIODIVERSITY IN THE GULF OF THAILAND UNDER THE MA SCENARIOS [S 10.4]

The Gulf of Thailand, a shallow tropical coastal shelf system, has experienced heavy exploitation over the last decades. Large long-lived fish species have widely vanished and fisheries concentrate on invertebrates. All four scenarios foresee a decline in biomass diversity for the Gulf of Thailand, with few species dominating the system. Under the *TechnoGarden* scenario, ecosystem management allows for a temporary increase in species diversity beginning in 2010. A turn in policy focus on producing fishmeal for the increasingly important aquaculture leaves the biomass diversity rapidly decreasing between 2030 and 2050. Similar changes are foreseen by the *Global Orchestration* and the *Adapting Mosaic* scenario, while the *Order from Strength* scenario lets the biodiversity index decline steadily over the next 50 years.

Policy Response Gaps

The following list of policy response gaps relate to issues that policy so far has not or has only inadequately addressed. It is recognized that the list may not necessarily be complete and that there are likely to be other policy response gaps. The reasons for many of the gaps range from the issues being insufficiently understood to the lack of political commitment.

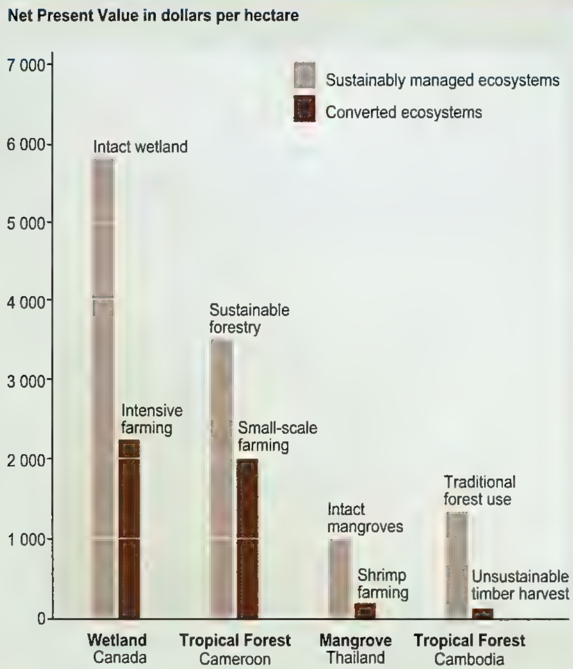
- *Dealing with genetic resources within marine and coastal national jurisdictions.* Marine and coastal areas may have considerable potential for bioactive compounds; however, many governments have not developed policies to ensure that these resources are used for the benefit of wider society. Similarly, the introduction of industries such as aquaculture also has the potential to impact on the genetic vigour of fish stocks, and few governments have policies or regulations in place to deal with such issues.
- *Lack of integration across sectors.* Policies are often lacking in dealing with a range of impacts such as inclusion of agricultural issues in marine and coastal areas so that an integrated response can be developed.
- *Policy responses to high-seas conservation issues.* There is no single international agency which is mandated to coordinate the many options for planning and management of the high seas; until an approach is developed to undertake such tasks, the high seas and associated resources will continue to be threatened by inappropriate exploitation practices.

Box 4.11 CASE STUDY: THE COSTS AND BENEFITS OF RETAINING OR CONVERTING NATURAL MANGROVE ECOSYSTEMS IN THAILAND

Relatively few studies have compared the total economic value of ecosystems under alternate management regimes. The total economic value (TEV) of managing a natural mangrove more sustainably was compared with converting it to other uses. In the case of aquaculture, the benefit of managing the ecosystem more sustainably exceeded that of the converted ecosystem.

Although conversion for aquaculture made sense in terms of short-term private benefits, it did not once external costs were factored in. The global benefits of carbon sequestration were considered to be similar in intact and degraded systems. However, the substantial social benefits associated with the original mangrove cover—from timber, charcoal, non-wood forest products, offshore fisheries, and storm protection—fell to almost zero following conversion. Summing all measured goods and services, the TEV of intact mangroves was a minimum of $1,000 and possibly as high as $36,000 per hectare, compared with the TEV of shrimp farming, which was about $200 per hectare (see Fig. 4.1).

Figure 4.1 ECONOMIC BENEFITS UNDER ALTERNATIVE MANAGEMENT PRACTICES



Source: Millennium Ecosystem Assessment.

- *Consistent policy measures to encourage compliance relating to high-seas initiatives (for example, fish stock and compliance agreements).* Although there are internationally agreed plans of action, how they are implemented varies between countries.
- *Understanding of the benefits and costs of MPAs.* There are few quantitative studies on the benefits and costs of marine protected areas, especially outside of tropical areas in national waters, for decision-makers to draw on.
- *Understanding of uncertainty and the methods to quantify it.* The nature of working in marine environments makes it difficult to capture long-term data or to ensure that the methods used are consistent, in turn this makes it difficult to measure uncertainty and to test methods to measure uncertainty, thus often hindering implementation of novel/new policy responses. In the face of uncertainty, management approaches that are robust to the uncertainties and are consistent with the requirements of the precautionary approach must be implemented.
- *Valuation studies for a range of marine resources and activities so that trade-off analyses and other policy responses can be better measured and assessed.* Globally there are few studies that provide information on the direct and indirect use values of marine and coastal resources except for commercial fisheries.
- *Understanding of the outcomes for ecosystem conditions of ICZM.* Assessments of the impacts of integrated coastal zone management have largely focused on processes rather than outcomes.
- *MPA and ICM success stories.* Scaling up is difficult because there are few examples of marine protected areas and integrated coastal management success stories. Policy responses at international and national levels have fewer examples or success stories and even fewer evaluations, especially of lessons learned from mistakes.
- *Long-term monitoring of the impacts of policy options.* The collection of long-term trend data is critical to assessing the effectiveness of particular policy responses as well as their appropriateness.
- *Understanding of why current policies to prevent oil spills are ineffective.* Oil spills are still causing severe impacts on coastal ecosystems, after a long history of failed attempts at addressing them.
- *Proactive or adaptive policy frameworks that have the ability to deal with managing new/emerging issues quickly and effectively.* An example is the lack of an effective policy framework for off-shore wind farms.

Ultimately, the continuing degradation and loss of the services provided by marine and coastal ecosystems that we depend on are putting human well-being at risk. It is the responsibility of every one of us—guided by the millennium development goals—to help halt and reverse these trends to ensure that these benefits are available for both present and future generations.

APPENDIXES

APPENDIX 1

A SELECTION OF INTERNATIONAL MECHANISMS IN THE MARINE AND COASTAL AREA

Global Legally Binding Agreements

United Nations Convention on the Law of the Sea (UNCLOS)

Convention on Biological Diversity (CBD)

United Nations Framework Convention on Climate Change (UNFCCC)

Convention on Wetlands of International Importance (Ramsar Convention)

UNEP Regional Seas Programme with the Regional Seas Conventions and Action Plans

Convention on International Watercourses

International Convention for the Prevention of Pollution from Ships

International Convention for the Control and Management of Ships' Ballast Water and Sediments

World Trade Organization's Agreement on Sanitary and Phytosanitary Measures

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

International Convention for the Regulation of Whaling (ICRW)

Convention on the Conservation of Migratory Species of Wild Animals (CMS), with the following agreements:

- Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS)
- Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)
- Agreement on the Conservation of Seals in the Wadden Sea
- Agreement on the Conservation of Albatrosses and Petrels
- Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa
- Memorandum of Understanding on the Conservation and Management of Marine Turtles and Their Habitats of the Indian Ocean and South-East Asia (IOSEA)

Other Global and Regional Mechanisms

Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)

United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks

European Water Framework Directive

Land-Ocean Interactions in the Coastal Zone Initiative (LOICZ)

FAO Code of Conduct for Responsible Fisheries

FAO International Plans of Action on reducing seabird bycatch; conserving shark fisheries; reducing fishing capacity; and reducing illegal, unreported, and unregulated fisheries

The International Coral Reef Initiative (ICRI) and its Operational Networks, including the International Coral Reef Action Network (ICRAN) and the Global Coral Reef Monitoring Network (GCRMN)

The Commission for the Conservation of Antarctic Marine Living Resources

The Johannesburg Plan of Implementation of the World Summit on Sustainable Development (WSSD)

Inter-American Convention for the Protection and Conservation of Sea Turtles (IACPCST)

APPENDIX 2

CHAPTERS IN THE MAIN MA VOLUMES

Ecosystems and Human Well-being: a Framework for Assessment

CF 1 Introduction and Conceptual Framework
CF 2 Ecosystems and Their Services
CF 3 Ecosystems and Human Well-being
CF 4 Drivers of Change in Ecosystems and Their Services
CF 5 Dealing with Scale
CF 6 Concepts of Ecosystem Value and Valuation Approaches
CF 7 Analytical Approaches
CF 8 Strategic Interventions, Response Options, and Decision-making

Current State and Trends: Findings of the Condition and Trends Working Group

Summary
CT 1 MA Conceptual Framework
CT 2 Analytical Approaches for Assessing Ecosystems and Human Well-being
CT 3 Drivers of Change (*note: this is a synopsis of Scenarios Chapter 7*)
CT 4 Biodiversity
CT 5 Ecosystem Conditions and Human Well-being
CT 6 Vulnerable People and Places
CT 7 Fresh Water
CT 8 Food
CT 9 Timber, Fuel, and Fiber
CT 10 New Products and Industries from Biodiversity
CT 11 Biological Regulation of Ecosystem Services
CT 12 Nutrient Cycling
CT 13 Climate and Air Quality
CT 14 Human Health: Ecosystem Regulation of Infectious Diseases
CT 15 Waste Processing and Detoxification
CT 16 Regulation of Natural Hazards: Floods and Fires
CT 17 Cultural and Amenity Services
CT 18 Marine Fisheries Systems
CT 19 Coastal Systems
CT 20 Inland Water Systems
CT 21 Forest and Woodland Systems
CT 22 Dryland Systems
CT 23 Island Systems
CT.24 Mountain Systems
CT 25 Polar Systems
CT 26 Cultivated Systems
CT 27 Urban Systems
CT 28 Synthesis

Scenarios: Findings of the Scenarios Working Group

Summary
S 1 MA Conceptual Framework
S 2 Global Scenarios in Historic Perspective
S 3 Ecology in Global Scenarios
S 4 State of Art in Simulating Future Changes in Ecosystem Services
S 5 Scenarios for Ecosystem Services: Rationale and Overview
S 6 Methodology for Developing the MA Scenarios
S 7 Drivers of Change in Ecosystem Condition and Services
S 8 Four Scenarios
S 9 Changes in Ecosystem Services and Their Drivers across the Scenarios
S 10 Biodiversity across Scenarios
S 11 Human Well-being across Scenarios
S 12 Interactions among Ecosystem Services
S 13 Lessons Learned for Scenario Analysis
S 14 Policy Synthesis for Key Stakeholders

Policy Responses: Findings of the Responses Working Group

Summary
R 1 MA Conceptual Framework
R 2 Typology of Responses
R 3 Assessing Responses
R 4 Recognizing Uncertainties in Evaluating Responses
R 5 Biodiversity
R 6 Food and Ecosystems
R 7 Freshwater Ecosystem Services
R 8 Wood, Fuelwood, and Non-wood Forest Products
R 9 Nutrient Management
R 10 Waste Management, Processing, and Detoxification
R 11 Flood and Storm Control
R 12 Ecosystems and Vector-borne Disease Control
R 13 Climate Change
R 14 Cultural Services
R.15 Integrated Responses
R 16 Consequences and Options for Human Health
R 17 Consequences of Responses on Human Well-being and Poverty Reduction
R 18 Choosing Responses
R 19 Implications for Achieving the Millennium Development Goals

Multiscale Assessments: Findings of the Sub-Global Assessments Working Group

Summary
SG 1 MA Conceptual Framework
SG 2 Overview of the MA Sub-global Assessments
SG 3 Linking Ecosystem Services and Human Well-being
SG 4 The Multiscale Approach
SG 5 Using Multiple Knowledge Systems: Benefits and Challenges
SG 6 Assessment Process
SG 7 Drivers of Ecosystem Change
SG 8 Condition and Trends of Ecosystem Services and Biodiversity
SG 9 Responses to Ecosystem Cjamge amd Their Impacts on Human Well-being
SG 10 Sub-global Scenarios
SG 11 Communities, Ecosystems, and Livelihoods
SG 12 Reflections and Lessons Learned

Sub-Global Assessments

SG-Caribbean Caribbean Sea
SG-CBC Coastal British Columbia
SG-SafMA Southern African Assessment
SG-Portugal Portugal Assessment
SG-PNG Papua New Guinea

Millennium Ecosystem Assessment Publications

Technical Volumes
(available from Island Press)

Ecosystems and Human Well-being: A Framework for Assessment

Current State and Trends: Findings of the Condition and Trends Working Group, Volume 1

Scenarios: Findings of the Responses Working Group, Volume 2

Policy Responses: Findings of the Responses Working Group, Volume 3

Multiscale Assessments: Findings of the Sub-global Assessments Working Group, Volume 4

Our Human Planet: Summary for Decision-makers

Synthesis Reports
(available at www.Maweb.org)

Ecosystems and Human Well-being: Synthesis

Ecosystems and Human Well-being: Biodiversity Synthesis

Ecosystems and Human Well-being: Desertification Synthesis

Ecosystems and Human Well-being: Human Health Synthesis

Ecosystems and Human Well-being: Wetlands Synthesis

Ecosystems and Human Well-being: Opportunities and Challenges for Business and Industry

APPENDIX 3

OTHER USEFUL RESOURCES

Below is a selected list of additional resources. Many of the sources included below will be able to point readers towards more detailed information, in addition to the chapters in Appendix 2.

Global Resources

Convention on Wetlands (Ramsar Convention): A number of resources such as guidelines for environmental impact assessment and communication and public awareness may be downloaded from the website: www.ramsar.org. Information about mangroves (www.ramsar.org/types_mangroves.htm) and coral reefs (www.ramsar.org/types_coral.htm) is also available.

Global Biodiversity Outlook 2001: A periodic report on biodiversity published by the Secretariat of the Convention on Biological Diversity. Copies are available upon request from the Secretariat: www.biodiv.org/gbo/default.asp.

Global Environmental Outlook (GEO): A participatory and regionally distributed assessment process with a strong capacity building component: www.unep.org.geo.

Global International Waters Assessment (GIWA): A comprehensive and integrated global assessment of international waters, their ecological status, and the causes of environmental problems in 66 regions of the world: www.giwa.net.

Global Programme of Action for the Protection of the Marine Environment from Land-based Activities: A source of conceptual and practical guidance to be drawn upon by national and/or regional authorities for devising and implementing sustained action to prevent, reduce, control, and/or eliminate marine degradation from land-based activities: www.gpa.unep.org/about/index.html.

The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP): Covers all scientific aspects on the prevention, reduction, and control of the degradation of the marine environment to sustain life support systems, resources, and amenities. Reports may be downloaded from http://gesamp.imo.org. Of particular interest is report number 70, A Sea of Trouble, and number 71, Protecting the Oceans from Land-based Activities.

International Coral Reef Initiative Forum (ICRIForum): Provides a range of various on-line resources related to coral reefs. Its purpose is to concentrate the various kinds

of information related to reefs that members might find helpful: www.icriforum.org.

International Geosphere-Biosphere Programme (IGBP): Not exclusively marine, but has produced a number of scientific reports for marine and coastal ecosystems, that may be downloaded from: www.igbp.kva.se/cgi-bin/php/frameset.php.

IUCN Marine Programme: Provides information and links to other marine sources. Publications may also be downloaded: www.iucn.org/themes/marine.

Land-Ocean Interactions in the Coastal Zone (LOICZ): Engages in research such as basin studies to inform the scientific community, policy-makers, managers, and stakeholders on the relevance of global environmental change in the coastal zone. A numbers of tools and studies can be downloaded from www.loicz.org.

Large Marine Ecosystems of the World (LME): A global effort to improve long-term sustainability of resources and the environment. Reports and data are available to download
www.edc.uri.edu/lme.

Millennium Development Goals (MDGs): The eight MDGs aim to substantially improve the lives of people around the world by 2015:
www.un.org/millenniumgoals.

Millenium Ecosystem Assessment (MA): All chapters and reports are available to download, and information and findings from the various sub-global assessments of the MA: www.MAweb.org.

Small Island Developing States Network: Aims to link SIDS to information and communication technologies to ensure sustainability of their resources. Information and key documents may be downloaded from: www.sidsnet.org.

The Global Ocean Observing System (GOOS): A permanent global system for observations, modelling, and analysis of marine and ocean variables to support operational ocean services worldwide: http://ioc.unesco.org/goos.

The State of World Fisheries and Aquaculture (SOFIA): Produces reports (available electronically) every two years with the purpose of providing a comprehensive, objective, and global view of capture fisheries and aquaculture, including associated policy issues:
www.fao.org/sof/sofia/index_en.htm

UNEP-World Conservation Monitoring Centre: The marine programme has produced a number of reports on marine and coastal issues as part of its biodiversity series. These may be downloaded from:
www.unep-wcmc.org
/resources/publications/UNEP_WCMC_bio_
series.

WWF Marine and Coastal Ecosystems Programme: Various reports produced by WWF can be downloaded from:
www.wwf.org.uk/researcher/issues/livingseas
/index.asp.

Regional Resources

After the Tsunami, Rapid Environmental Assessment: A UNEP-produced report on the environmental impact of the tsunami that occurred in the Indian Ocean on 26 December 2004. Is available to download from:
www.unep.org/PDF/Tsunami_assessment_re
port/TSUNAMI_report_complete.pdf.

Bay of Bengal Large Marine Project: A regional project focusing on the marine and coastal areas within the Bay of Bengal. Information and reports can be downloaded from:
www.fao.org/fi/boblme/website/index.htm.

European Iron Fertilization Experiment (EIFEX): A project focusing on adaptation strategies of Southern Ocean (SO) phytoplankton to iron limitation prevalent in the high nutrient – low chlorophyll (HNLC) regions of the SO. Further information may be found at: www.ifm-geomar.de/index.php?id=2079&L=1.

Regional Seas Programme: An action-oriented programme that focuses not only on the mitigation or elimination of the consequences but also on the causes of environmental degradation. Regional action plans can be downloaded from
www.unep.org/water/regseas/regseas.htm.

National Resources

Bangladesh

Bangladesh coastal policy: An example of a national coastal policy including downloadable documents may be found at: www.iczmpbangladesh.org.

United States of America

The PEW Ocean Commission: A scientific examination of America's oceans. A full report is available to download at
www.pewtrusts.org/pdf/env_pew_oceans_fin
al_report.pdf and individual scientific reports are also available to download from www.pewtrusts.org.

U.S. Commission on Ocean Policy: Produced recommendations for a coordinated and comprehensive national ocean policy. Documents are available to download from:
www.oceancommission.gov.

APPENDIX 4

GLOSSARY OF TERMS

Abundance The total number of individuals of a taxon or taxa in an area, population, or community. Relative abundance refers to the total number of individuals of one taxon compared with the total number of individuals of all other taxa in an area, volume, or community.

Adaptation Adjustment in natural or human systems to a new or changing environment. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Alien species Species introduced outside its normal distribution.

Aquaculture Breeding and rearing of fish, shellfish, or plants in ponds, enclosures, or other forms of confinement in fresh or marine waters for the direct harvest of the product.

Bio-calcification The laying down of calcium carbonate by living tissue.

Biodiversity (a contraction of biological diversity) The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species, and between ecosystems.

Biological diversity See *Biodiversity*.

Biomass The mass of tissues in living organisms in a population, ecosystem, or spatial unit.

Biome The largest unit of ecological classification that is convenient to recognize below the entire globe. Terrestrial biomes are typically based on dominant vegetation structure (e.g., forest, grassland). Ecosystems within a biome function in a broadly similar way, although they may have very different species composition. For example, all forests share certain properties regarding nutrient cycling, disturbance, and biomass that are different from the properties of grasslands. Marine biomes are typically based on biogeochemical properties. The WWF biome classification is used in the MA.

Biopiracy The predatory use of biological resources by corporation. Particular activities usually covered by the term are: unauthorized use of biological resources; unauthorized use of traditional communities' knowledge on biological resources; unequal share of benefits between a patent holder and the indigenous community whose resource and/or knowledge has been used; and patenting of biological resources with no respect to patentable criteria.

Bioprospecting The exploration of biodiversity for genetic and biochemical resources of social or commercial value.

Capital asset An asset that is recorded as capital, i.e., property that creates more property.

Capture fisheries See *Fishery*.

Carbon sequestration The process of increasing the carbon content of a reservoir other than the atmosphere.

Cascading interaction See *Trophic cascade*.

Catch The number or weight of all fish caught by fishing operations, whether the fish are landed or not.

Coastal system Systems containing terrestrial areas dominated by ocean influences of tides and marine aerosols, plus nearshore marine areas. The inland extent of coastal ecosystems is the line where land-based influences dominate, up to a maximum of 100 kilometres from the coastline or 100-metre elevation (whichever is closer to the sea), and the outward extent is the 50-metre-depth contour. See also *System*.

Community (ecological) An assemblage of species occurring in the same space or time, often linked by biotic interactions such as competition or predation.

Community (human, local) A collection of human beings who have something in common. A local community is a fairly small group of people who share a common place of residence and a set of institutions based on this fact, but the word 'community' is also used to refer to larger collections of people who have something else in common (e.g., national community, donor community).

Cultural services The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.

Decision-maker A person whose decisions, and the actions that follow from them, can influence a condition, process, or issue under consideration.

Deforestation Conversion of forest to non-forest.

Desertification Land degradation in drylands resulting from various factors, including climatic variations and human activities.

Diversity The variety and relative abundance of different entities in a sample.

Driver Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem.

Driver, direct A driver that unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. (Compare *Driver, indirect*.)

Driver, indirect A driver that operates by altering the level or rate of change of one or more direct drivers. (Compare *Driver, direct*.)

Ecosystem A dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit.

Ecosystem approach A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use. An ecosystem approach is based on the application of appropriate scientific methods focused on levels of biological organization, which encompass the essential structure, processes, functions, and interactions among organisms and their environment. It recognizes that humans, with their cultural diversity, are an integral component of many ecosystems.

Ecosystem assessment A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers.

Ecosystem change Any variation in the state, outputs, or structure of an ecosystem.

Ecosystem function See *Ecosystem process*.

Ecosystem management An approach to maintaining or restoring the composition, structure, function, and delivery of services of natural and modified ecosystems for the goal of achieving sustainability. It is based on an adaptive, collaboratively developed vision of desired future conditions that

integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework, and defined primarily by natural ecological boundaries.

Ecosystem process An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem services The benefits people obtain from ecosystems. These include *provisioning services* such as food and water; *regulating services* such as flood and disease control; *cultural services* such as spiritual, recreational, and cultural benefits; and *supporting services* such as nutrient cycling that maintain the conditions for life on Earth. The concept 'ecosystem goods and services' is synonymous with ecosystem services.

Endangered species Species that face a very high risk of extinction in the wild. See also *Threatened species*.

Endemic (in ecology) A species or higher taxonomic unit found only within a specific area.

Endemism The fraction of species that is endemic relative to the total number of species found in a specific area.

Equity Fairness of rights, distribution, and access. Depending on context, this can refer to resources, services, or power.

Eutrophication The increase in additions of nutrients to freshwater or marine systems, which leads to increases in plant growth and often to undesirable changes in ecosystem structure and function.

Fishery A particular kind of fishing activity, e.g., a trawl fishery, or a particular species targeted, e.g., a cod fishery or salmon fishery.

Freedom The range of options a person has in deciding the kind of life to lead.

Globalization The increasing integration of economies and societies around the world, particularly through trade and financial flows, and the transfer of culture and technology.

Global scale The geographical realm encompassing all of Earth.

Governance The process of regulating human behaviour in accordance with shared objectives. The term includes both governmental and nongovernmental mechanisms.

Gyres A major circular moving body of water. It is created as boundary currents get deflected by winds and the Coriolis Effect. There are five gyres in our world ocean. Two gyres occur in each of the Pacific and the Atlantic Oceans and one in the Indian Ocean. They flow clockwise in the Northern Hemisphere and counter-clockwise in the Southern Hemisphere. (Source: Ocean World Glossary http://oceanworld.tamu.edu/students/currents/currents4.htm)

Health, human A state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity. The health of a whole community or population is reflected in measurements of disease incidence and prevalence, age-specific death rates, and life expectancy.

High seas The area outside national jurisdiction, i.e., beyond each nation's exclusive economic zone or other territorial waters.

Human well-being See *Well-being*.

Indicator Information based on measured data used to represent a particular attribute, characteristic, or property of a system.

Inland water systems Permanent water bodies other than salt-water systems on the coast, seas, and oceans. Includes rivers, lakes, reservoirs, wetlands, and inland saline lakes and marshes. See also *System*.

Institutions The rules that guide how people within societies live, work, and interact with each other. Formal institutions are written or codified rules. Examples of formal institutions would be the constitution, the judiciary laws, the organized market, and property rights. Informal institutions are rules governed by social and behavioural norms of the society, family, or community. Also referred to as organizations.

Interventions See *Responses*.

Invasive alien species An alien species whose establishment and spread modifies ecosystems, habitats, or species.

Island systems Lands isolated by surrounding water, with a high proportion of coast to hinterland. The degree of isolation from the mainland in both natural and social aspects is accounted by the *isola effect*. See also *System*.

Keystone species A species whose impact on the community is disproportionately large relative to its abundance. Effects can be produced by consumption (trophic interactions), competition, mutualism, dispersal, pollination, disease, or habitat modification (nontrophic interactions).

Land cover The physical coverage of land, usually expressed in terms of vegetation cover or lack of it. Related to, but not synonymous with, *land use*.

Landscape An area of land that contains a mosaic of ecosystems, including human-dominated ecosystems. The term cultural landscape is often used when referring to landscapes containing significant human populations or in which there has been significant human influence on the land.

Landscape unit A portion of relatively homogenous land cover within the local-to-regional landscape.

Marginal benefits Extra benefits arising from increased consumption of a commodity.

Marine system Marine waters from the low-water mark to the high seas that support marine capture fisheries, as well as deepwater (>50 metres) habitats. Four sub-divisions (marine biomes) are recognized: the coastal boundary zone; trade-winds; westerlies; and polar.

Market-based instruments Mechanisms that create a market for ecosystem services in order to improve the efficiency in the way the service is used. The term is used for mechanisms that create new markets, but also for responses such as taxes, subsidies, or regulations that affect existing markets.

Mitigation An anthropogenic intervention to reduce negative or unsustainable uses of ecosystems or to enhance sustainable practices.

Nutrient cycling The processes by which elements are extracted from their mineral, aquatic, or atmospheric sources or recycled from their organic forms, converting them to the ionic form in which biotic uptake occurs and ultimately returning them to the atmosphere, water, or soil.

Nutrients The approximately 20 chemical elements known to be essential for the growth of living organisms, including nitrogen, sulphur, phosphorus, and carbon.

Open access resource A good or service over which no property rights are recognized.

Population, human A collection of living people in a given area. Compare *Community (human, local)*.

Poverty The pronounced deprivation of well-being. Income poverty refers to a particular formulation expressed solely in terms of per capita or household income.

Prediction (or forecast) The result of an attempt to produce a most likely description or estimate of the actual evolution of a variable or system in the future. See also *Projection* and *Scenario*.

Primary productivity The amount of production of living organic material through photosynthesis by plants, including algae, measured over a period of time.

Projection A potential future evolution of a quantity or set of quantities, often computed with the aid of a model. Projections are distinguished from 'predictions' in order to emphasize that projections involve assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized; they are therefore subject to substantial uncertainty.

Property rights The right to specific uses, perhaps including exchange in a market, of ecosystems and their services.

Provisioning services The products obtained from ecosystems, including, for example, genetic resources, food and fibre, and freshwater.

Public good A good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted.

Realm Used to describe the three major types of ecosystems on Earth: terrestrial, freshwater, and marine. Differs fundamentally from *biogeographic realm*.

Regime shift A rapid reorganization of an ecosystem from one relatively stable state to another.

Regulating services The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.

Relative strain index An index looking at air temperature and vapour pressure in defining climatic limits for human well-being.

Resilience The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Responses Human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems. In the context of ecosystem management, responses may be of legal, technical, institutional, economic, and behavioural nature and may operate at various spatial and time scales.

Riparian Something related to, living on, or located at the banks of a watercourse, usually a river or stream.

Salinization The build-up of salts in soils.

Scale The measurable dimensions of phenomena or observations. Expressed in physical units, such as metres, years, population size, or quantities moved or exchanged. In observation, scale determines the relative fineness and coarseness of different detail and the selectivity among patterns these data may form.

Scenario A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a 'narrative storyline'. Scenarios may include projections but are often based on additional information from other sources.

Security Access to resources, safety, and the ability to live in a predictable and controllable environment.

Service See *Ecosystem services*.

Species An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term *species* is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity, that once described and accepted is associated with a unique scientific name.

Species diversity Biodiversity at the species level, often combining aspects of species richness, their relative abundance, and their dissimilarity.

Species richness The number of species within a given sample, community, or area.

Stock (in fisheries) The population or biomass of a fishery resource. Such stocks are usually identified by their location. They can be, but are not always, genetically discrete from other stocks.

Storyline A narrative description of a scenario, which highlights its main features and the relationships between the scenario's driving forces and its main features.

Strategies See *Responses*.

Subsistence An activity in which the output is mostly for the use of the individual person doing it, or their family, and which is a significant component of their livelihood.

Supporting services Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

Sustainable use (of an ecosystem) Human use of an ecosystem so that it may yield a continuous benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

Sustainability A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

System In the Millennium Ecosystem Assessment, reporting units that are ecosystem-based but at a level of aggregation far higher than that usually applied to ecosystems. Thus the system includes many component ecosystems, some of which may not strongly interact with each other, that may be spatially separate, or that may be of a different type to the ecosystems that constitute the

majority, or matrix, of the system overall. The system includes the social and economic systems that have an impact on and are affected by the ecosystems included within it. For example, the Condition and Trends Working Group refers to 'forest systems', 'cultivated systems', 'mountain systems', and so on. Systems thus defined are not mutually exclusive, and are permitted to overlap spatially or conceptually. For instance, the 'cultivated system' may include areas of 'dryland system' and vice versa.

Taxon (pl. taxa) The named classification unit to which individuals or sets of species are assigned. Higher taxa are those above the species level. For example, the common mouse, *Mus musculus*, belongs to the Genus *Mus*, the Family Muridae, and the Class Mammalia.

Taxonomy A system of nested categories (*taxa*) reflecting evolutionary relationships or morphological similarity.

Threshold A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behaviour, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Trade-off Management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided by ecosystems.

Trend A pattern of change over time, over and above short-term fluctuations.

Trophic level The average level of an organism within a food web, with plants having a trophic level of 1, herbivores 2, first-order carnivores 3, and so on.

Uncertainty An expression of the degree to which a future condition (e.g., of an ecosystem) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined terminology or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (e.g., a range of values calculated by various models) or by qualitative statements (e.g., reflecting the judgment of a team of experts).

Urbanization An increase in the proportion of the population living in urban areas.

Valuation The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on). See also *Value*.

Value The contribution of an action or object to user-specified goals, objectives, or conditions. Compare *Valuation*.

Vulnerability Exposure to contingencies and stress, and the difficulty in coping with them. Three major dimensions of vulnerability are involved: exposure to stresses, perturbations, and shocks; the sensitivity of people, places, ecosystems, and species to the stress or perturbation, including their capacity to anticipate and cope with the stress; and the resilience of the exposed people, places, ecosystems, and species in terms of their capacity to absorb shocks and perturbations while maintaining function.

Watershed (also catchment basin) The land area that drains into a particular watercourse or body of water. Sometimes used to describe the dividing line of high ground between two catchment basins.

Well-being A context- and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience.

Wetlands Areas of marsh, fen, peat land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. May incorporate riparian and coastal zones adjacent to the wetlands and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands.

APPENDIX 5

ABBREVIATIONS AND ACRONYMS

ACCOBAMS – Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
ACS – Association of Caribbean States
AIGA – alternative forms of income generation
ASCOBANS – Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas

CARICOM – Caribbean Community
CBD – Convention on Biological Diversity
CCCL – coastal construction control lines
CF – Conceptual Framework
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS – Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention)
CSS – combined storm and sewer systems
CT – *Condition and Trends* volume of the MA

DEWA – Division of Early Warning and Assessment (UNEP)

EEZ – exclusive economic zone
EIA – environmental impact assessment
ENSO – El Niño/Southern Oscillation

FAO – Food and Agriculture Organization (United Nations)

GCRMN – Global Coral Reef Monitoring Network
GDP – gross domestic product
GEO – Global Environment Outlook
GESAMP – The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIWA – Global International Waters Assessment
GMA – Global Marine Assessment
GNP – gross national product
GPA – Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
GPS – Global Positioning System

ICCAT – International Commission for the Conservation of Atlantic Tuna
ICRAN – International Coral Reef Action Network
ICRI – International Coral Reef Initiative
ICRW – International Convention for the Regulation of Whaling
ICZM – integrated coastal zone management
IGBP – International Geosphere-Biosphere Programme
IOSEA – Memorandum of Understanding on the Conservation and Management of Marine Turtles and Their Habitats of the Indian Ocean and South-East Asia
IPCC – Intergovernmental Panel on Climate Change
IQ – individual quota
ISA – infectious salmon anaemia
ITQ – individual transferable quota
IUCN – World Conservation Union

LIFDC – low-income food-deficit countries
LME – large marine ecosystems
LOICZ – Land-Ocean Interactions in the Coastal Zone
LPI – Living Planet Index

MA – Millennium Ecosystem Assessment
MCA – multicriteria analysis
MDG – Millennium Development Goal
MPA – marine protected area
MSY – maximum sustainable yield

NAFO – North West Atlantic Fisheries Organization
NEAFC – North East Atlantic Fisheries Commission
NGO – nongovernmental organization

OAS – Organization of American States
OECD – Organisation for Economic Co-operation and Development

PCBs – polychlorinated biphenyls
POPs – persistent organic pollutants

R – *Responses* volume of the MA

S – *Scenarios* volume of the MA
SDM – Summary for Decision-makers (of the MA)
SIDS – small island developing states
SG – *Sub-global Assessment* volume of the MA
SOFIA – State of World Fisheries and Aquaculture (FAO)
SR – Synthesis Report (of the MA)

TEK – traditional ecological knowledge
TEV – total economic value

UBC – University of British Colombia
UN – United Nations
UNCCD – United Nations Convention to Combat Desertification
UNCLOS – United Nations Convention on the Law of the Sea
UNDP – United Nations Development Programme
UNEP – United Nations Environment Programme
UNFCCC – United Nations Framework Convention on Climate Change

WCMC – World Conservation Monitoring Centre (of UNEP)
WCPA – World Commission on Protected Areas
WSSD – World Summit on Sustainable Development
WWF – World Wide Fund For Nature

[1] The Millennium Development Goals commit the international community to a commonly accepted framework for measuring development progress. The eight goals set targets on overcoming poverty, illiteracy, hunger, lack of education, gender inequality, child and maternal mortality, disease, and environmental degradation.

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